

**POTENTIAL OCCUPATIONAL EXPOSURE TO DURABLE
FIBERS DUE TO SUBSTITUTION FOR ASBESTOS FIBERS**

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December 20, 1985

Draft

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EXECUTIVE SUMMARY

EPA is assessing the potential risks associated with the production and use of products designed to replace or compete with products containing asbestos. EPA is particularly concerned about respirable/durable fibers. Durable means fibers which are non-biodegradable and can survive in biological systems for long periods of time; and respirable means fibers with diameters less than 3 microns which can enter the small airways leading to the lungs. The study of durable fiber replacements for asbestos has been divided into two parts: an exposure assessment and a health effects assessment.

In this report, we summarize the available information from literature and through industry contacts concerning the extent of occupational exposure to durable fibers during the process of making asbestos product substitutes. The effort also focuses on determining the physical characteristics of non-asbestos fibers especially regarding their respirability. In addition, we summarize available information concerning the potential occupational exposure to durable fibers during the downstream fabrication (secondary processing), servicing, and use of three product categories: friction materials, textiles (particularly carded textiles), and reinforced plastic molding compounds. We focused on these three product categories as they seemed to pose the greatest potential for downstream exposure due to fiber size reduction during primary manufacture (e.g., grinding, extrusion, roll milling, carding, etc.)

Primary Product Manufacture

ICF performed a study entitled Asbestos Products and Their Substitutes in 1984. This study was used to identify the fibers which can substitute for

asbestos in asbestos containing products (see Appendix A). Thirty asbestos products were identified and grouped into the following seven product categories to characterize emissions:

- Paper and felt products;
- Friction materials;
- Liquid products;
- Textile products;
- Rolled products;
- Asbestos-cement sheet; and
- Reinforced plastic molding compounds.

Table E-1 summarizes the process steps for each product category which may potentially cause airborne fiber exposures. During manufacture, the fiber feed and mixing steps allow for the greatest opportunity for airborne fiber emissions since fiber feed is often manual and mixing vats are sometimes open vats. Cutting, molding, and grinding steps may also cause fibers to break off the product and become airborne. There was no written documentation confirming that airborne fibers are generated from these process steps or indicating which step creates the most fly (airborne fibers).

Table E-2 indicates the level of automation used by each industry sector. Information on the level of automation used in textile and asbestos-cement product manufacture was not provided by the industry contacts. Fiber feed is typically manual; an operator with or without personal protective equipment slits open the fiber bag and dumps it into the mixing vessel or onto a conveyor belt. Some manufacturers of paper and felt products, friction materials, and rolled products have automated fiber feed systems using bag opening machines or fiber transfer directly from storage towers (no bag opening required). These differences in bag opening techniques indicate variation within these three industries.

Table E-1. Process Steps Causing Potential Airborne Fiber Exposures
During Primary Manufacture of Asbestos Substitute Products

| Product Category | Process Step |
|--------------------------------------|--|
| Paper and Felt Products | <ul style="list-style-type: none"> • Fiber Feed • Mixing • Sheet Cutting |
| Friction Products | <ul style="list-style-type: none"> • Fiber Feed • Fiber Fluffing (Aramids) • Mixing • Cutting and Grinding |
| Liquid Products | <ul style="list-style-type: none"> • Fiber Feed • Mixing |
| Textile Products | <ul style="list-style-type: none"> • Fiber Feed • Carding |
| Rolled Products | <ul style="list-style-type: none"> • Fiber Feed • Mixing • Sheet Cutting |
| Asbestos-Cement Products | <ul style="list-style-type: none"> • Fiber Feed • Mixing • Cutting and Molding |
| Reinforced Plastic Molding Compounds | <ul style="list-style-type: none"> • Fiber Feed • Mixing • Extruding/Roll Milling^a • Grinding^a |

^a

May be closed systems -- not confirmed.

Source: Industry Contacts, May-June 1985.

Table E-2. Level of Automation of Primary Production Processes

| Product Category | Manual Operations | Automatic Operations |
|--------------------------------------|---|--|
| Paper and Felt Products | <ul style="list-style-type: none"> o Fiber feed^a o Transfer of packaged roll to warehouse | <ul style="list-style-type: none"> o Fiber feed^a o Mixing o Papermaking o Sheet cutting o Roll packaging |
| Friction Materials | <ul style="list-style-type: none"> o Fiber feed^a o Material transfer from machine to machine^a | <ul style="list-style-type: none"> o Fiber feed^a o Mixing o Material transfer from machine to machine^a o Sheet formation o Molding o Grinding and drilling |
| Liquid Products | <ul style="list-style-type: none"> o Fiber feed o Putting lids on full drums of product | <ul style="list-style-type: none"> o Mixing o Transfer to packaging o Packaging |
| Textile Products | NK | NK |
| Rolled Products | <ul style="list-style-type: none"> o Fiber feed^a o Emptying mixers onto conveyors | <ul style="list-style-type: none"> o Fiber feed^a o Completely closed and continuous^a |
| Asbestos-Cement Products | NK | NK |
| Reinforced Plastic Molding Compounds | <ul style="list-style-type: none"> o Fiber feed o Putting lids on full drums of product | <ul style="list-style-type: none"> o Mixing o Roll milling or extrusion o Grinding o Packaging |

NK = Not Known.

^a

Fiber feed systems are highly variable for this industry -- some are totally automatic and others are manual.

Source: Industry Contacts, May-June 1985.

For all product categories, the processes appear to be highly automated once the fiber is introduced. The fiber is automatically processed and packaged. An operator is usually needed at the end of the line to simply put lids on the filled containers or to transfer the packaged product to the storage area. The friction material and rolled product sectors show variation in the level of automation used by each company. For friction materials, some companies use manual material transfer from machine to machine (each machine, however, is automated), and some companies are completely automatic including material transfer. For rolled products, some companies may require an operator to manually empty the mixed material onto a conveyor belt which begins the continuous process, and some companies have completely closed and continuous processes including fiber feed.

In addition to the use of automated equipment to reduce potential human exposures to airborne fibers, other exposure control equipment is often used. Table E-3 summarizes the level of exposure control used by each industry sector. Ventilation is typically used above mixing vessels and areas where dusting may occur. In some cases, the ventilation equipment is put in place to protect operators from organic vapors instead of airborne fibers. The difference with fume hoods designed to control organic vapor concentrations within the plant and hoods designed to control fiber levels is that fume hoods exhaust to the atmosphere and do not collect the airborne fiber. Respirators (or masks), coveralls, and gloves are typically made available to employees in most of the product areas. Depending on company policy, the use of personal protective equipment may be optional or mandatory. Some manufacturers do not consider the asbestos replacements to be potentially dangerous and, therefore, leave it up to the employees to decide what level of protection they desire.

Table E-3. Level of Exposure Control
During Primary Manufacture

| Product Category | Ventilation | Respirators | Coveralls/Gloves |
|--------------------------------------|---------------------|--------------|--------------------------------------|
| Paper and Felt Products | Some | Some (Masks) | Some |
| Friction Materials | Yes | NK | Yes (gloves when steel wool is used) |
| Liquid Products | Yes | Yes (Masks) | Yes |
| Textile Products | Some (Over Looms) | No | No |
| Rolled Products | ^a Yes | Some (Masks) | NK |
| Asbestos-Cement Products | Yes | Some | Some |
| Reinforced Plastic Molding Compounds | Yes | Some | Yes (gloves) |

NK = Not Known.

^a

For solvents mainly.

Source: Industry Contacts, May-June 1985.

Some employees choose to use the personal protective equipment while others do not.

Table E-4 indicates the number of operators directly exposed in each type of process. Only a small number of workers (typically 5 or less) are exposed to the fibers in each plant. Two facilities contacted had more than 10 workers who could potentially be exposed. We have been unable to estimate the total number of employees exposed to asbestos replacement fibers used in these products because the size of the industries (number of facilities or production lines) is not currently available.

Table E-5 summarizes the data collected on input fiber sizes. We obtained data on all the suitable durable fiber replacements for asbestos in friction materials and reinforced plastic molding compounds. Fairly good coverage for fiberglass dimensions used in each type of product were also found. The data, however, is incomplete. Some manufacturers (friction materials, liquid products, asbestos-cement products) use proprietary fiber blends and would not provide information on fiber sizes. In addition to the fibers shown in Table E-5, we did not obtain data about alumina, calcium silicate, polyester, teflon, acrylic, nylon, phenol-formaldehyde, polybenzimidazole, or silica fiber sizes.

The available data indicates that fiber sizes used vary widely both across product categories and fiber types. For fiberglass, textile products use long (1-1/2 to 2 inches), thin (6 micron diameter) fibers while friction materials use short (1/8 inch), thicker (13 micron diameter) fibers. For reinforced plastic molding compounds, fiber diameters used are typically in the range from 4 to 6 microns or 10 to 14 microns, but fiber lengths vary widely with fiber type from as low as 0.01 mm for Wollastonite to as high as 1/2-inch for some aramid fibers.

Table E-4. Number of Operators Directly Exposed to Durable Fibers
During Primary Product Manufacture

| Product Category | Number of Operators Per Line |
|--------------------------------------|---------------------------------|
| Paper and Felt Products | |
| • Roofing Felt | 2-3 |
| • Pipeline Wrap | > 10 |
| Friction Materials | NK |
| Liquid Products | 2-4 |
| Textile Products | |
| • Carding Process | 2-3 |
| • Continuous Filament Process | 3-6 |
| Rolled Products | |
| • Compressed Sheet Gaskets | 1-3 |
| Asbestos-Cement Products | NK |
| Reinforced Plastic Molding Compounds | ^a 15 |

^a

There are 100 employees in the specific facility contacted. 15 of these 100 employees work with the raw materials.

Source: Industry Contacts, May-June 1985.

Table E-5. Fiber-Feed Sizes for Asbestos Product Substitutes

| Product Category | Specific Product | Aramid | | Calcium Sulfate | | Carbon | | Cellulose | | Ceramic ^c | |
|--------------------------------------|------------------------------|---------------|---------------------------------------|-----------------|-------------|---------------|-------------|---------------|-------------|----------------------|-------------|
| | | Diameter (um) | Length (mm) | Diameter (um) | Length (mm) | Diameter (um) | Length (mm) | Diameter (um) | Length (mm) | Diameter (um) | Length (mm) |
| Paper and Felt Products | Paper | 12 | 0.5-8.0 | - | - | - | - | NK | NK | NK | NK |
| | Roofing Felt | | | - | - | - | - | NK | NK | NK | NK |
| | Board | | | - | - | - | - | NK | NK | NK | NK |
| | Appliance Insulation | | | - | - | - | - | NK | NK | NK | NK |
| | Micropore Filters | | | - | - | - | - | NK | NK | NK | NK |
| Friction Materials | General | 12 | 6-12 ^a 2-4 ^b | 2 | 0.05 | 11 | 6.35 | 18 | 0.08 | 2 | 0.31 |
| Liquid Products | Roof Coatings | - | - | - | - | - | - | NK | - | - | - |
| Textile Products | Carding | NK | 38.1-102 | - | - | - | - | - | - | NK | NK |
| | Continuous Filament | NK | | - | - | - | - | - | - | NK | NK |
| Rolled Products | Fiber-Reinforced Floor Tiles | NK | | - | - | - | - | 15 | 1.5 | NK | NK |
| Asbestos-Cement Products | General | - | - | - | - | - | - | - | - | - | - |
| Reinforced Plastic Molding Compounds | General | 12 | 6.4-12.7 | 4.6 | 0.4-0.6 | 5-8 | 6.4 | - | - | - | - |

um = micron.

mm = millimeter.

- = Not a Substitute.

NK = Not Known.

^a Short Fiber.^b Pulp.^c Ceramic fibers generally produced with a nominal diameter of 2-4 microns with range of individual diameters from 0.5 to 12 microns - skewed towards the larger diameter fiber. (Source: TIMA)

Source: Industry Contacts, May-June 1985.

Table E-5 (Continued)

| Product Category | Specific Product | Fiberglass | | Graphite | | Mineral | | Polyethylene/ Polypropylene | | Steel Wool | | Wollastonite | |
|--|---------------------------------|------------------|----------------|------------------|----------------|------------------|----------------|--------------------------------|----------------|------------------|----------------|------------------|----------------|
| | | Diameter (um) | Length (mm) | Diameter (um) | Length (mm) | Diameter (um) | Length (mm) | Diameter (um) | Length (mm) | Diameter (um) | Length (mm) | Diameter (um) | Length (mm) |
| Paper and Felt Products | Paper | 2-3 | 6.4-25.4 | - | - | NK | - | NK | - | - | - | - | - |
| | Roofing Felt | 10-16 | 12.7-25.4 | - | - | NK | - | NK | - | - | - | - | - |
| | Board | 9.5 | NK | - | - | NK | - | NK | - | - | - | - | - |
| | Appliance | 6.4 | NK | - | - | NK | - | NK | - | - | - | - | - |
| | Insulation | - | - | - | - | - | - | - | - | - | - | - | - |
| | Micropore Filters | 1 | NK | - | - | NK | - | NK | - | - | - | - | - |
| Friction Materials | General | 13 | 3.2 | 8.4 | 6.35 | 10 | 0.03 | - | - | 13-114 | 0.8-2.0 | - | - |
| Liquid Products | Roof Coatings | NK | - | - | - | - | - | 10-40 | 0.6-1.2 | - | - | - | - |
| Textile Products | Carding | 6 | 38.1-50.8 | - | - | - | - | - | - | - | - | - | - |
| | Continuous Filament | 3-13 | Continuous | - | - | - | - | - | - | - | - | - | - |
| Rolled Products | Fiber-Reinforced Floor Tiles | NK | - | NK | - | - | - | NK | - | - | - | - | - |
| Asbestos-Cement Products | General | 13 | 3.2-38.1 | - | - | - | - | - | - | - | - | - | - |
| Reinforced Plastic Molding Compounds | General | 4-6 10-14 | 3.2-6.4 | - | - | 4-6 | 0.16-0.36 | - | - | - | - | 3.5 | 0.01-0.07 |

um = micron.

mm = millimeter.

- = Not a Substitute.

NK = Not Known.

a Short Fiber.

b Pulp.

Source: Industry Contacts, May-June 1985.

The data found for input fiber sizes does not necessarily indicate the fiber sizes of airborne fibers. The data provided in Table E-5 are nominal fiber lengths and diameters; there is generally a wide distribution of the fiber dimensions around the nominal values. Little data on actual fiber emissions or fiber size distributions was found. It should be noted that only asbestos is covered by a specific OSHA standard and that all other fibers are covered by nuisance dust rules. Table E-6 reports the results of the four exposure studies we located.

The first exposure study measured total airborne dust levels for a facility making roofing felt with mineral wool. Total airborne dust levels (which include mineral fibers) for the three samples taken at the felt rewinder ranged from 0.95 to 1.17 mg/m³. Compared to the Threshold Limit Values (TLVs)* set for nuisance dust, 10 mg/m³, the exposure to airborne dusts in this facility is quite low.

The second exposure study measured ceramic fiber levels at various stages of a continuous filament textile production line. The ceramic fibers used to make the textiles have 11 micron diameters and are continuous filaments. The airborne fiber levels ranged from 0.000007 to 0.00005 fibers per cubic centimeter (cc), with an average of 0.00004 fibers per cc. Even compared to the TLVs set for asbestos, 0.2 to 2 fibers per cubic centimeter depending on asbestos form, the exposure to airborne fibers in this facility are extremely low. It appears that airborne fibers are so low because continuous filaments are used instead of chopped fibers. The fiber size distribution for airborne

* TLVs are recommended levels set by the American Conference of Government Industrial Hygienists.

Table E-6. Summary of Available Exposure Data

| Product Category | Product | Fiber | Fiber Exposure |
|-------------------------|---|--|---|
| Paper and Felt Products | Roofing Felt | Mineral Wool | 0.95-1.17 mg/m ³ total airborne dust ^a |
| Textile Products | Continuous Filament Textiles (11 micron diameter) | Ceramic Fibers | Range: 0.000007-0.00005 fibers/cc 108-792 micron length 8.1-13.5 micron diameter Average: 0.00004 fibers/cc 261 micron length 10 micron diameter |
| Friction Materials | Friction Products | Proprietary blend of fibers (aramid, mineral fibers) | Range: 0.01-0.07 fibers/cc |
| Rolled Products | Compressed Sheet Gaskets | Aramid Fibers | Range: 0.01-0.09 fibers/cc Average: 0.05 fibers/cc |

^a
Measured at the felt rewinder.

Sources: U.S. Department of Labor, Occupational Safety and Health Administration, Appleton Area Office, Appleton, WI, Sampling Data of Genstar Building Materials Company, June 22, 1983. Environmental Protection Agency, Office of Pesticides and Toxic Substances, "Proceedings of the National Workshop on Substitutes for Asbestos," November, 1980, p. 438. E.I. Dupont de Nemours & Company, Internal Report: Monitoring Data of Dupont's Customers' Plants, 1982.

fibers ranged from 108 to 792 microns for fiber length (with an average of 261 microns), and from 8.1 to 13.5 microns for fiber diameter (with an average of 10 microns). -

The third exposure study, conducted by DuPont, measured the airborne dust levels at a friction materials production plant. The airborne fiber levels ranged from 0.01 to 0.07 fibers per cubic centimeter; the average fiber count was not reported. This plant used a proprietary blend of fibers which may include aramid and mineral fibers.

The fourth study measured total airborne dust levels (also monitored by Dupont) for a facility making compressed sheet gaskets. The airborne dust levels measured in five samples taken at the plant ranged from 0.01 to 0.09.. fibers per cubic centimeter with an average of 0.05 fibers per cubic centimeter. Aramid fibers were used in the gasket-making process.

OSHA has little/no data for fiber exposures other than asbestos during the manufacture of these products. Two reports on fiberglass exposure during roofing felt production and saturation were found, but the facilities measured had since closed. However, a NIOSH document on a proposed fibrous glass standard was available.* The recommended fiberglass standard for workplace air is 3 fibers/cubic centimeter, having a diameter less than or equal to 3.5 microns and a length greater than or equal to 10 microns, determined as a TWA (time weighted average) concentration for up to a 10-hour work shift in a 40-hour work week.

* National Institute for Occupational Safety and Health, Occupational Exposure to Fibrous Glass, Washington, D.C., 1977, pp. 3-82.

In virtually all occupational situations where fibrous glass is present, the exposure is not to fibers of uniform diameter, but to a range which usually includes a percentage of fibers having diameters which are considered to be of respirable size. The distribution of glass fibers by diameter for air taken from occupational environments, fibrous glass-lined ventilation systems, and ambient air reported by Balzer* is presented in Figure E-1. The diameter of glass fibers measured in ambient air and ventilation systems had mean diameters of 4.3 and 3.7 microns, respectively. Samples taken during the installation of fibrous glass insulation materials had an average fiber diameter of 6.5 microns. Approximately 15 percent of the fibers from the occupational environment are less than 3 microns in diameter (respirable size). The mean concentrations of fibers for each of the three sampling sources are 0.003 fibers/cc in ambient air, 0.0008 fibers/cc in ventilation systems, and 0.4 fibers/cc during the installation of insulation materials.

The work of Fowler et al. determined that insulation workers were exposed to airborne concentrations of glass fibers ranging from 0.5 to 8 fibers/cc with a median of 1.3 fibers/cc and a mean of 1.8 fibers/cc during the actual application of fibrous glass insulation products.+

Secondary Product Manufacture and Use

The information gathered during the investigation of potential exposures during primary manufacturing indicated that fiber size is reduced during the manufacture of three asbestos substitute product categories: friction

* Balzer, J.L., "Environmental Data; Airborne Concentrations Found in Various Operations in Occupational Exposure to Fibrous Glass," National Institute for Occupational Safety and Health, 1976.

+ Fowler, D.P., Balzer, J.L., Cooper W.C., "Exposure of Insulation Workers to Airborne Fibrous Glass," American Industrial Hygiene Association 32:86-91, 1971.

minor sources of fiber exposure should the brakes have a layer of fiber dust remaining on them from the factory. Used brakes are sent to rebuilders who remove the worn lining or block from the brake shoe, another potential exposure process, and replace it with new lining.

During the manufacture of fire-resistant clothing, the fabric cutting and sewing steps allow for the greatest opportunity for airborne fiber emissions since fibers will be broken during cutting, and sewing is a manual operation. During molding of reinforced plastic products, the molding compound handling and feeding, and the product finishing steps allow for the greatest opportunity for airborne fiber emissions because the feed operations are only semi-automated, and the finishing operations include grinding and other processes which generate dust and are often manual. There was no written documentation confirming that airborne fibers are generated from these process steps or indicating which step creates the most fly (airborne fibers).

Table E-8 indicates the level of automation used by each industry sector. For friction products (e.g., brakes), the processes of brake assembly and rebuilding are automated; even the removal of the brake lining or block, which contain the asbestos substitute, from the brake shoes is performed on automated deriveters or shearing equipment. However, servicing and replacement of brakes are manual operations and may be significant sources of fiber exposure.

For textiles, textile cutting is performed on automated machines; however, the cut pieces are manually sewn together by hand or on regular sewing machines. The sewing machine operators will be handling the cut fabric directly.

Table E-8. Level of Automation of Secondary Production Processes and Handling

| Product Category | Manual Operations | Automatic Operations |
|--|---|---|
| Friction Products -- Post-Manufacture Handling and Use | o Cleaning of Wheel and Brake Assembly During Brake Replacement | o Removal of Brake Blocks and Linings from Shoes o Brake Shoe Cleaning (Shot Blasting) o Brake Assembly |
| Textile Products -- Secondary Manufacture | o Sewing | o Cutting |
| Reinforced Plastic Molding Compounds -- Secondary Molding | o Machining of Molded Product* o Replacement of Vacuum System Filter and Fiber Collection Drums | o Introduction of Molding Compound to the Press (Semi-Automated Mechanical or Pneumatic Transfer) o Molding Compound Heating and Injection o Molding and Curing |

* Some companies have automated finishing operations.

Source: Industry Contacts, November-December 1985.

Table E-9. Level of Exposure Control
During Secondary Production Processes and Handling

| Product Category | Ventilation (Local) | Respirators | Coveralls/ Gloves | Eye Protection |
|---|------------------------|---|----------------------|-------------------------|
| Friction Products -- Post-Manufacture Handling and Use | | | | |
| o Brake Assembly | No | Yes (Dust Mask) | Yes (Coats) | Yes (Safety Glasses) |
| o Brake Shoe Rebuilding | No | Yes (Masks) | Yes (Gloves) | Yes (Goggles) |
| o Wheel Assembly Cleaning During Brake Replacement | No | Sometimes (Dust Mask) | No | No -- / |
| Textile Products -- Secondary Manufacture | | | | |
| o Manufacture of Fire-Resistant Clothing | No | No | No | No |
| Reinforced Plastic Molding Compounds -- Secondary Molding | | | | |
| | Yes | No (Maintenance personnel may wear dust mask or full protective gear) | No | No |

Source: Industry Contacts, November-December 1985.

Table E-10. Number of Operators Directly Exposed to Durable Fibers
During Secondary Product Manufacture and Handling

| Product Category | Number of Operators Directly Exposed at a Facility |
|---|---|
| Friction Products -- Post-Manufacture Handling and Use | 6 (Full Service Garage) |
| Textile Products -- Secondary Manufacture | |
| • Cutting | 1-3 |
| • Sewing | 10-15 (35-40 total facility employment)* |
| Reinforced Plastic Molding Compounds -- Secondary Molding | 4-30 (per shift for 1-3 shifts)+ |

*
Facilities manufacture other products in addition to fire-resistant clothing.

+
Highly variable depending on level of automation and production.

Source: Industry Contacts, November-December 1985.

fire-resistant clothing and reinforced plastic molding employ a larger number of potentially exposed workers than was observed for the primary production operations. The reason for the large number of employees is that some of the process steps are highly labor intensive such as manual sewing and finishing steps. Some plastic product molding facilities automate the finishing operations and, therefore, require fewer operators as indicated by the low end of the range. Brake servicing and rebuilding shops tend to be quite small with respect to the number of employees. We have been unable to estimate the total number of employees exposed to asbestos replacement fibers used in these products because the size of the industries (number of facilities) is not currently available.

Steel wool used to make semi-metallic disc brake pads is the largest substitute for asbestos in brakes. Semi-metallic brakes are commonly used on front wheel drive automobiles; asbestos brakes are still in use for rear wheel drive vehicles. Some aramid fiber is used as a substitute for asbestos in disc brake pads and drum brake linings. Fiberglass, ceramic, and aramid fibers are used to substitute asbestos in textiles. Fiberglass is the main replacement for asbestos in reinforced plastic molding compounds, and fiberglass has already completely replaced asbestos in general products such as pot handles. The fiber input sizes for these products are presented in Table E-5. Data on the level of substitute fiber exposure and the airborne fiber size distribution for secondary processes was not available although it appears that some companies (e.g., Hoover Vacuum, Lapcor Plastics, and Delco Products) have monitored for nuisance dust.

I. INTRODUCTION/METHODOLOGY

EPA is evaluating the potential risks associated with the production and use of asbestos substitute products. EPA is particularly concerned about respirable durable fibers. Durable fibers are those fibers which are slowly biodegraded or are non-biodegradable and can survive in biological systems for long periods of time; respirable fibers are those fibers with diameters less than 3 microns which can enter the small airways leading to the lungs. The purpose of this preliminary survey is to seek information about the manufacturing processes for and the post-manufacturing handling of these asbestos substitute products, and to characterize the physical characteristics of the fibers used. Our approach consists of five steps as follows:

- Identify asbestos product substitutes and determine which products are made with durable fibers;
- Categorize the products made with durable fibers by manufacturing process and by type of fiber;
- Seek information about these manufacturing processes and post-manufacture handling and use, focusing on the nature of the durable fiber emission process;
- Investigate the size distribution of the fibers emitted and whether this distribution is an inflexible outcome of the products' manufacturing process; and
- Seek occupational exposure data on fiber emissions from fiber product manufacturers.

Our methodology is presented below.

A. Methodology

ICF performed a study entitled Asbestos Products and Their Substitutes in 1984. This study was used as our reference for identifying the fibers which can substitute for asbestos in asbestos containing products. Thirty asbestos product subcategories were identified (see Appendix A and Table A-1). Our first step was to make a list of all the products and the fibers which are

suitable replacements for asbestos in these products (see Table A-1). Most of the substitute products are made with durable fibers. Notable exceptions are the substitutes for some specialty papers, chemically-resistant coatings and linings, and asbestos-cement pipe.

The asbestos products with durable fiber substitutes are so numerous that we needed to categorize them before a more detailed manufacturing emissions analysis could be performed. We made two divisions of the asbestos products and substitutes: 1) types of processes -- to characterize the nature of the emissions process; and 2) types of fibers -- to determine which fibers should be focused on. We developed seven categories of products based on manufacturing process similarity as follows:

- Paper and felt products;
- Friction materials;
- Liquid products;
- Textile products;
- Rolled products;
- Asbestos-cement products; and
- Reinforced plastic molding compounds.

The 30 asbestos product subcategories are assigned to one of these categories as shown in Table 1. Table 2 lists the potential fiber replacements for asbestos in each product category. Each of these fibers is defined in Appendix B. Our approach was to search for exposure information on as many of these fiber replacements as possible as they relate to each product category. Many of the same fibers are used to make products in different categories.

Our approach involved searching for information about manufacturing processes and emission controls, size distribution of fibers emitted, and occupational exposure. To find information about manufacturing processes, we performed a literature search using the PTS Prompt and Compendex data bases. The search approach combined "product," "manufacturing or production process," and "fiber". This search unearthed only a few articles. Review of the

Table 1. Major Product Categories^a

| Product Category | Asbestos Product |
|--------------------------------------|---|
| Paper and Felt Products | Asbestos Flooring Felt Asbestos Felt-Backed Vinyl Sheet Flooring Saturated Roofing Felt Unsaturated Roofing Felt Pipeline Wrap Specialty Papers High-Grade Electrical Paper Beater-Add Gaskets Millboard Rollboard Commercial Paper Corrugated Paper |
| Friction Materials | Brake Blocks (for heavy duty vehicles) Clutch facings Automatic Transmission Components Disc Brake Pads (heavy vehicles) Disc Brake Pads (light & medium vehicles) Drum Brake Linings (light & medium vehicles) Friction Materials |
| Liquid Products | Adhesives and Sealants Paints and Surface Coatings |
| Textile Products | Asbestos Textiles |
| Rolled Products | Asbestos Sheet Gasketing Asbestos Packing Vinyl-Asbestos Floor Tile |
| Asbestos-Cement Products | Asbestos-Cement Pipe Corrugated Asbestos-Cement Sheets Flat Asbestos-Cement Sheet Asbestos Cement Shingles |
| Reinforced Plastic Molding Compounds | Asbestos-Reinforced Plastics |

^a

See Table A-1 for details.

Table 2. Fiber Replacement for Asbestos in Each Product Category^a

| Product Category | Fiber Replacements |
|--------------------|---|
| Paper and Felt | Alumina Aramid Calcium Silicate Cellulose Ceramic Fiberglass Mineral Wool Organic Polyester Polyethylene/Polypropylene Teflon |
| Friction Materials | Aramid Cellulose Fiberglass Carbon Ceramic Wollastonite Mineral Fibers Steel Wool |
| Liquid Products | Acrylic Homopolymer Cellulose Fiberglass Nylon Polyethylene/Polypropylene |
| Textile Products | Acrylic Aramid Ceramic Fiberglass Phenol-formaldehyde Polymer Polybenzimidazole Polyester Silica |
| Rolled Products | Acrylic Aramid Cellulose Ceramic Fiberglass Graphite Polyethylene/Polypropylene Silica Teflon |

Table 2 (Continued)

| Product Category | Fiber Replacements |
|--------------------------------------|---|
| Asbestos-Cement Products | Fiberglass |
| Reinforced Plastic Molding Compounds | Aramid Carbon Fiberglass Processed Mineral Fiber Wollastonite |

^a
See Table A-1 for details.

abstracts of these articles indicated that they did not contain information on fiber emissions or emission controls used by industry. Our next step involved contacting the following six organizations to obtain either information about processes or suggestions about where we might find such information:

- Man-Made Fiber Producers Association -- Washington, D.C.
- Albany International Research -- Dedham, Massachusetts
- Industrial Fabrics Association International -- St. Paul, Minnesota
- International Society of Industrial Fabric Manufacturers -- Gastonia, North Carolina
- DuPont -- Wilmington, Delaware
- Institute of Paper Chemistry -- Appleton, Wisconsin
- Thermal Insulation Manufacturers Association-- Mt. Kisco, New York.

Some general process information was provided and the following handbooks were suggested:

- Wellington-Sears Handbook of Industrial Textiles (Ernest R. Kaswell);
- Textile Technology Digest;
- World Textile Abstracts; and
- Man-Made Fibers (Moncrief).

The major focus of these handbooks is to describe in detail the processes used to make consumer and industrial textiles. Information about fiber sizes used to make various textiles and potential fiber exposures during each process are not discussed. The consensus of the organizations listed above was that product manufacturers would have to be contacted directly to obtain fiber size distributions and exposure levels.

In seeking information on occupational exposure, we hoped to find data on exposure levels and fiber size distributions for various fibers for various product manufacturing processes. Our first step involved a variety of searches using Compendex I, Compendex II, PTS Prompt, MEDLINE, and Toxline data bases. Exposure data for fiberglass and mineral wool appeared to be reasonably abundant but was specific to the manufacture of the fibers themselves, not to the manufacture or use of the final asbestos substitute products. Our next step was to go through the OSHA index of reports to find available reports about each fiber substitute. These reports include NIOSH "Hazard Evaluation and Technical Assistance Reports (HHEs)," "Industry Wide Study Reports (IWs)," "Control Technology Reports (CTs or Walk-Through Survey Reports)", and "Contractor Reports". We reviewed all of the available reports at the OSHA Technical Center. Two reports about fiberglass exposure during the production and saturation of roofing felts were found. These reports were based on monitoring done in the 1970s as indicated in the following references:

- J.M. Dement, K.M. Wallingford, R.D. Zumwalde, NIOSH, Industrial Hygiene Survey of Owens-Corning Fiberglass, Kansas City, Kansas, May 24, 1973.
- NIOSH (Report #76-55-443), Health Hazard Evaluation Determination, Certain-Teed Products, Takoma, Washington, November 1977.

Because this data was relatively old, we contacted the companies to see if operations had changed since the time of these reports. Both facilities have since closed. A company representative at Owens-Corning said its Kansas City, Kansas roofing felt mill closed in November 1979.* A company representative of Certain-Teed said its Takoma, Washington roofing felt saturating facility

* Owens-Corning, telephone conversation with company representative in Aiken, South Carolina on May 29, 1985.

closed in 1984.* The exposure data for these two facilities have not been presented in this report because the facilities have since closed and the data is old and may not represent current practices of other facilities. Exposure data for other fibers and products are not available due to the limited number of site visits made by NIOSH with respect to these fibers. In addition, only asbestos fibers are covered by a specific OSHA standard; all other fibers are only covered by nuisance dust rules.

Having exhausted the literature and having found only minimal information, we decided that the best approach to attaining information on potential exposures was to contact the product manufacturers, handlers, and users directly. Substitute product manufacturer's names were provided in ICF's 1984 report, Asbestos Products and Their Substitutes. Our approach was to ask for information on fiber handling, process automation and emission controls, input fiber sizes, and number of exposed employees.

The information obtained from the substitute product manufacturers concerning fiber size reduction (via extrusion, grinding, roll milling, or carding) during processing was used to identify products which were likely to pose potential exposure to durable fibers during downstream fabrication, handling, and use. Friction materials, reinforced plastic molding compounds, and textile products (particularly carded textiles) appear to be the products with the greatest potential for downstream exposure because of the fiber size reduction which occurs during the primary manufacture of these products.

The manufacturers contacted for each product category are listed in Table 3 with an indication of the type of person contacted and whether or not

* Certain-Teed, telephone conversation with company representative in Savannah, Georgia on May 28, 1985.

Table 3. Summary of Contacts

PART A

| Product Category | Company | Information Provided | | Position of Person Contacted |
|--------------------------------------|--------------------------------------|----------------------|----|-----------------------------------|
| | | Yes | No | |
| Paper and Felt Products | Johns-Manville | X | | Marketing/Sales |
| | Manning Paper | X | | NK |
| | Nicolet | X | | NK |
| | Carborundum | | X | Technical Specialist |
| | GAF | | X | NK |
| | Genstar | X | | Plant Manager |
| | Lydall Technical Papers | X | | Process Control Engineer |
| | Lydall Technical Papers | X | | Process Engineer |
| Friction Materials | Owens-Corning | X | | Plant Superintendent |
| | Owens-Corning | | | |
| | General Motors | X | | Manager of Market Development |
| | Nuturn | X | | NK |
| | Carlisle Motion Control Industries | X | | Research and Development Engineer |
| | Durawool | X | | NK |
| | Bendix, Friction Materials Division | X | | Environmental Division |
| | Scan-Pac | | X | NK |
| Liquid Products | Celotex Roofing Products | | X | Department Manager |
| | Dudick Corrosion-Proof Manufacturing | X | | Sales Representative |
| | Tremco | X | | Director of Research |
| | Hercules | X | | Project Manager, Pulpex Fiber |
| | Gibson-Homans | X | | Quality Control & Formulations |
| Textiles | Celanese | X | | Product Specialist |
| | Newtex Industries | X | | Technical Representative |
| | Amatex | X | | Assistant Plant Manager |
| Rolled Products | Monsanto | X | | Product Representative |
| Asbestos-Cement Products | H.H. Robertson | | X | NK |
| | Cem-FIL | X | | NK |
| | Manville | X | | NK |
| Reinforced Plastic Molding Compounds | Certain-Teed | X | | Customer Inquiries Department |
| | DuPont | X | | NK |
| | Union Carbide | X | | Sales Representative |
| | Hercules | X | | Sales Representative |
| | Celanese | X | | NK |
| | Rogers Corporation | X | | Operations Manager |

NK = Not known.

Table 3 (Continued)

| PART B | | | | |
|--|--------------------------------------|----------------------|-----------|---|
| Product Category | Company | Information Provided | | Position of Person Contacted |
| | | Yes | No | |
| Friction Products -- Post-Manufacture Handling and Use | American Trucking Association | X | | Engineering |
| | Auto Parts Rebuilders Association | X | | Technical Service |
| | Barker Brake | X | | NK |
| | Bendix, Friction Materials Division | X | | NK |
| | Carlisle Motion Control Industries | X | | Safety Engineer |
| | EIS Division of Parker Hannifin | X | | NK |
| | Industrial Brake and Supply | X | | NK |
| | Precision Import Service | X | | Owner |
| | Sears Roebuck, Automotive Service | X | | Mechanic |
| Textile Products -- Secondary Manufacturing | DuPont, Haskel Laboratory | X | | Sales Representative |
| | New Tex Industry | X | | Sales Representative |
| | B & D Supply | X | | General Manager |
| | Fyrepel | X | | Production Manager |
| | Rockland Fire Department | X | X | Production Manager |
| | Man-Made Fiber Producers Association | X | | Technical Director on Flame-Retardant Clothing |
| United Textile Workers of America | X | | President | |
| Reinforced Plastic Molding Compounds -- Secondary Molding | Celion, Division of BASF | X | | Sales Engineer |
| | Hercules | X | | Sales Representative |
| | Lapcor Plastics | X | | Purchasing Agent/Manufacturing |
| | General Electric | | X | Manufacturing |
| | General Industries | | X | Manufacturing |
| | Certain - Teed | | X | Customer Inquiries |
| | Delco Products | | | NK |
| | Hoover Vacuum | X | | OSHA Liaison |
| | Plastic Engineering | X | | NK |
| | Resinoid Engineering | X | | NK |
| | Rogers Corporation | X | | Operations Manager |
| | Garfield Molding | | X | NK |
| | Sunbeam | X | | Manufacturing |

NK = Not known.

relevant information was obtained. For the most part, industry sources were quite helpful although they were not always able to provide all the information we needed either because of its proprietary nature or the contact's lack of knowledge. To get around the "lack of knowledge" obstacle, we contacted numerous types of company personnel to obtain the necessary data.

Unfortunately, data on all fiber substitutes could not be obtained in this limited screening effort. The information obtained for each product category is presented in the following sections.

In general, manufacturers either did not have exposure data for their processes or were unwilling to provide the data without a formal request from EPA (e.g., Carborundum, Hoover, and Lapcor). If exposure measurements had been taken by OSHA, the companies (e.g., Genstar Building Products -- roofing felt operations) were willing to give us this information. We also found some published data on exposures during textile manufacture. Unpublished company data were not offered for our review.

B. Organization of the Report

The report is divided into two parts. Part A discusses potential fiber exposure during primary product manufacture, and Part B discusses potential fiber exposure during secondary product manufacture and post-manufacture use. In Part A, each of the seven product categories is discussed separately. Within these sections, the product manufacturing processes, emission controls currently in use, fiber feed sizes for the asbestos replacements, number of directly exposed operators, and available exposure data are summarized. In Part B, each of the three product categories which appear to pose the greatest potential for exposure during secondary manufacture and use is discussed separately. In some situations, secondary manufacturing is the focus of the

discussion; and in other situations, post-manufacture handling, use, and servicing of the product is of key concern. Each chapter includes a list of industry contacts who provided the information from which the chapters were written. This collected information is compiled in the Executive Summary.

PART A
POTENTIAL FIBER EXPOSURE DURING
PRIMARY PRODUCT MANUFACTURE

II. PAPER AND FELT PRODUCTS

This product category includes all products manufactured on conventional papermaking equipment: flooring felt, felt-backed vinyl sheet flooring, saturated and unsaturated roofing felts, pipeline wrap, beverage and pharmaceutical filters, high-grade electrical paper, beater-add gaskets, millboard, rollboard, commercial paper, and corrugated paper. Potential durable fiber replacements for asbestos in these products are fiberglass, ceramics, cellulose, polyethylene/polypropylene, aramids, teflon, mineral wool, alumina, and calcium silicate.

A. Manufacturing Process and Emission Controls

Paper and felt asbestos substitute products are categorized together because they are all made on conventional papermaking equipment. The basic process is shown in Figure 1. The fiber is introduced into a pulper where it is blended with large quantities of water (Manville feeds 10,000 gal/min). A cylinder with a wire web is immersed into the pulp mixture. The layer of wet pulp is pressed through rollers to remove excess water and is dried over steam heated drying cans. Some felts (e.g., roofing felts) are coated with a thermo-set resin prior to the drying step to provide the strength needed during saturation. The paper is then cut into appropriate sizes and is packaged for sale.

Paper products are typically made in a continuous sheet. Millboard is the exception. A cylinder rotates in a vat of pulp creating a thin fiber coating. This fiber is removed from the cylinder and is drawn through a press for partial dewatering. Sheets are wound continuously onto a cylindrical mold until the desired board thickness is obtained. Workers cut the damp material away from the cylinder to make one damp sheet of millboard which is then dried.

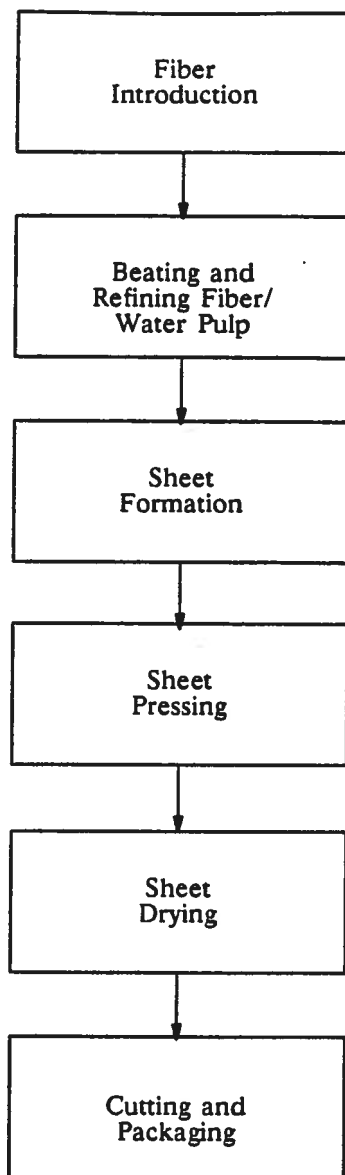


Figure 1. Paper and felt production process.

The area of greatest potential for exposure to fibers is the fiber introduction area. We spoke with four companies manufacturing roofing felts or pipeline wrap, and each had its own unique method of handling the raw fibers. Manville was by far the most automated facility. Because Manville manufactures glass fibers, the packaging/unpackaging step is avoided. Manville stores its fiber in huge tanks and at a moisture content of 14.5 percent. At this moisture level, the fibers are clumped together. This moisture is due to a wax sizing which is applied to the fibers to keep them separate and prevent abrasion. The fiber is automatically weighed into a 6-8 foot tall container on a forklift. The forklift operator drives over to the mixing vessel and automatically dumps the load into the vessel. There is no manual fiber handling. For roofing felts, the fibers are only blended with the water to create a uniform mixture; the fiber is not beaten as it would be for paper pulps. Once the sheet is produced, it is automatically sent to the automatic slitter which cuts the sheet into desired widths. The rolls are then wound-up and are automatically sealed with stretch film. The packaged felt is transferred via forklift to the storage area. The only manual handling of the material is the transfer of finished rolls to a smaller operation where thin sheets are made (less than 5 percent of the business). This auxiliary slitter and the stretch film wrapping of the finished product are automated, but boxing of the finished rolls is manual.

Owens-Corning receives large plastic bags of damp fiberglass which is coated with a surface active agent to help with dispersion in the water. The damp fibers are in clumps when dumped from the bags which Owens-Corning claims reduces the potential for airborne fibers. Bags are manually cut open and the contents are dumped into a hopper. The rest of the process is automatic including sheet slitting and wrapping in plastic. Exposure may occur during

mat cutting using a circular blade. Ventilation is used to control this dusting, and Owens-Corning claims its process runs very clean. No data was given to support the claim.

Genstar uses mineral wool to make its roofing felt. In addition to the mineral wool; pulp wood, scrap newspaper, and corrugated paper are also included in the felt mix. Bales of mineral wool (larger than bales of hay) are received by the plant. The bales are wrapped with kraft paper on two sides, and 3 to 6 bands hold the bales together. Bales are carried with a forklift to a conveyor belt. The bands are manually slit, and the kraft paper and bands are removed. No more human handling occurs until the felt is finished. During the felt slitting process, the wide sheets are cut into narrower rolls. Genstar claims that the most exposure to airborne fibers occurs during the roll wind-up.

Nicolet manufactures pipeline wrap. The fiber is delivered in bags which are moved from the truck to the pulper on a forklift. The entire bag including paper wrapping is dumped into the pulper. The bags are not opened in any way prior to introduction into the pulper. The bags are pulpable kraft and since they are making a paper product, the paper bag does not harm the mix. The entire process is automated from the pulper to the final roll form. If the product requires cutting, the roll is transferred manually from the papermaking machine to the slitter. The rolls are then cut and wrapped automatically. Pipeline wrap is a saturated product. The wrapped rolls are manually carried to the saturator which is automatic and is followed by an automatic slitter and packager. The contact said ventilation and coveralls/gloves are not used in the facility. This information may need to be confirmed. The paper machine and the saturator are operated on alternate weeks.

Most of the roofing felt facilities discussed above produce only the felt. The felt is sold to another company which saturates it with asphalt. Owens-Corning has a separate facility which saturates fiberglass mat. Rolls of fiberglass mat arrive wrapped in plastic. The mat is manually unwrapped and placed on a "looper". Owens-Corning claims that virtually no dust or particulate is around as the mat already has a resin coating on it (they were unable to provide us with any actual data). The looper unrolls the mat and pulls it taught. Owens-Corning told us that a very small amount (unknown) of dust is released when the mat is pulled taught. No special ventilation is used during this operation. In other areas of the saturating plant, dusts of other kinds are applied to the mat, and special ventilation is used.

Paper manufacturers typically have manual bag opening operations. Manning Paper makes electrical insulation paper with fiberglass. Bags are opened manually and the bag feeder wears a face mask and Tyvek® suit. The fiber is initially clumped which Manning claims minimizes potential exposure to airborne fibers; Manning was not able to provide data to support this claim.

Lydall manufactures beater-add gasket paper. The only information provided was that bags of Kevlar® are manually dumped into a hopper.

Lydall also manufactures commercial paper using ceramic fibers. Bags of fiber are manually opened and are dumped onto a conveyor which discharges them directly into the pulper where they are dispersed in water. The pulper is closed during its operation. This facility does not have local ventilation over the equipment. Masks are available but only approximately half of the operators wear them routinely. Lydall has monitored for asbestos, ceramics, and fiberglass in its facility and claims that fiber levels in the air have never been high; however, no actual data was given to support this claim.

B. Fiber Exposure

Information on directly exposed operators was provided by three companies. Manville says they have one person working the fiber feed forklift and one person working the product removal forklift in its roofing felt operation. Owens-Corning's roofing felt operation is similar. Owens-Corning has one person dumping bags, one person in the control room, and one person removing the finished products. Nicolet's pipeline wrap facility requires many more operators. There are 6 operators/shift for 3 shifts on the paper machine, 3 operators/shift for 1 shift on the slitter, and 1 operator/shift who unloads the fiber and loads the finished product. The number of operators on the saturating line was not obtained.

The Genstar Building Materials Company (Cornell, WI) which produces unsaturated mineral wool roofing felt, was inspected by OSHA in June 1983.* According to the present Plant Manager, although the inspection resulted in recommendations to require employees to wear protective masks, use creams, and wear protective clothing to reduce irritation caused by airborne mineral wool particulates, the employees objected to this requirement. Genstar, therefore, keeps the materials available to employees at all times but does not require their use.

The area of the felt production line monitored for airborne dust was the rewinder; three separate atmospheric samples were taken and the results are shown in Table 4.

* U.S. Dept. of Labor, Occupational Safety and Health Administration, Appleton Area Office, Appleton, WI. Sampling Data of Genstar Building Materials Company, June 22, 1983.

Table 4. Airborne Dust Monitoring Results
at Genstar Building Materials Company
(Unsaturated Roofing Felt Production)

| Sample Location | Operation | Contaminant | Exposure |
|---------------------|----------------|---------------|------------------------|
| #1 Machine Rewinder | Felt Rewinding | Airborne Dust | 1.17 mg/m ³ |
| #2 Machine Rewinder | (Same) | (Same) | 1.01 mg/m ³ |
| #2 Machine Rewinder | (Same) | (Same) | 0.95 mg/m ³ |

Source: U.S. Dept. of Labor, Occupational Safety and Health
Administration, Appleton Area Office, Appleton, WI.
Sampling Data of Genstar Building Materials Company,
June 22, 1983.

C. Fiber Sizes

Fiber size information was only found for fiberglass and Kevlar® in paper and felt products. No information was obtained for ceramics, cellulose, polyethylene/polypropylene, teflon, mineral wool, alumina, or calcium silicate fiber dimensions.

A spokesman for the Institute of Paper Chemistry says fiberglass with nominal diameters from 2 to 3 microns are used in papers. Diameters of less than 1 micron are used in micropore filters. A representative of Manning Paper says it uses fiber lengths between 1/4-inch (6,350 microns) and 1 inch (25,400 microns) for its electrical insulation paper. The average fiber diameter in fiberglass appliance insulation is about 6.4 microns, with 13.7 percent of the fibers having diameters less than 3 microns and 1.5 percent having diameters less than 1 micron. For board products, the average fiber diameter is 9.5 microns, with 12.5 percent of the fibers less than 3 microns in diameter and 1.9 percent less than 1 micron.*

Roofing felts use very large fibers compared to other paper products. Manville says all fibers have diameters greater than 10 microns, with 13 and 16 micron diameters being the most common. Ninety plus percent of the fiberglass fibers used are one inch long. Some fibers are 1/2-inch and 3/4-inch in length.

The distribution of airborne glass fiber diameters in air samples taken from occupational environments, fibrous glass-lined ventilation systems, and

* Jon L. Konzen, M.D., "Production Trends in Fiber Sizes of Man-Made Mineral Fiber (MMMF) Insulation," p. 4. Presentation at the WHO/EURO Conference on Biological Effects of Man-Made Mineral Fibers - Copenhagen, April 20-22, 1982.

ambient air was reported by Balzer (see Figure 2).* The mean diameters of glass fibers measured in ambient air and ventilation systems were 4.3 and 3.7 microns, respectively. Samples taken during the installation of fibrous glass insulation materials had an average fiber diameter of 6.5 microns. Fibers that are less than 3 microns in diameter (respirable range) constituted approximately 15 percent of the fibers from the occupational environment. The mean concentration of fibers in ambient air is 0.003 fibers/cc, 0.0008 fibers/cc in ventilation systems, and 0.4 fibers/cc during the installation of insulation materials.

DuPont's Kevlar® (aramid fiber) was described in a paper titled "Kevlar Aramid Pulp for Paper Making" supplied along with the Product Literature; it indicated a "nominal" fiber diameter of 12 microns with fine (curled or tangled) fibrils with sub-micron diameters attached to the surface. Fibrils are fine threadlike material into which a fiber can be longitudinally split. The fiber length indicated was 0.5 mm (0.02 in) to 8.0 mm (0.32 in). This information was consistent with a report prepared for EPA by JRB Associates (January 1985).+

These fiber sizes are nominal measurements; there is always a fiber size distribution around these nominal dimensions. In addition, the data presented are fiber-input sizes. Table 5 summarizes the fiber dimensions used in paper and felt products. The dimensions of airborne fibers may not be the same as the dimensions of input fiber; fiber size distributions for airborne fibers were not available.

* Balzer, J.L., "Environmental Data; Airborne Concentrations Found in Various Operations in Occupational Exposure to Fibrous Glass," National Institute for Occupational Safety and Health, 1976.

+ JRB Associates, Data Summaries and Hazard Assessments of Asbestos Substitutes, January 11, 1985.

Table 5. Dimensions of Fibers Used in Paper and Felt Products

| Fiber Type | Length (inches) | Diameter (microns) |
|---------------------|--------------------|--|
| Fiberglass | | |
| Paper Products | 0.25-1.0 | 2-3 |
| Insulation Products | - | 6.4 (15.2% have diameter less than 3 microns) |
| Board Products | - | 9.5 (14.4% have diameter less than 3 microns) |
| Roofing Felts | 1.0 | 10+ |
| Aramid | | |
| Paper Products | 0.02-0.32 | ^a 12 |

^a
"Nominal" fiber diameter.

D. Industry Contacts

The following list of industry sources were contacted during May 1985 to develop information on paper and felt products:

1. Carborundum Corporation
Greg LaBarge
Technical Specialist
Niagara Falls, New York
2. Certain-Teed
Jim Walls
Sales Representative
Savannah, Georgia
3. GAF
Gerard Vandermeys
Wayne, New Jersey
4. Genstar
Plant Manager
Cornell, Wisconsin
5. Institute of Paper Chemistry
Dr. Warren
Appleton, Wisconsin
6. Lydall Technical Papers
Ming Hay Huang
Process Control Engineer
Housnick Falls, New York
7. Lydall Technical Papers
Wes Dickford
Engineer
New Hampshire
8. Manning Paper
Troy, New York
9. Manville
Wayne Jackson
Marketing/Sales
Denver, Colorado
10. Nicolet
Norristown, Pennsylvania
11. Nicolet
Richelle Hittinger
Legal
Ambler, Pennsylvania

12. Owens-Corning
Randy Derant
Plant Superintendant
Jessup, Maryland

13. Owens-Corning
John Gambrel
Process Engineer
Aiken, South Carolina

III. FRICTION MATERIALS

Friction products containing fiber substitutes for asbestos are available for most applications. The same basic manufacturing process is used for all friction products, although there are variations depending on the end use of the product, the formulation, and the producer. The specific details of the manufacturing processes are considered proprietary. Friction products using substitute fibers generally contain a proprietary blend of fibers; the most widely used fibers are steel wool, aramid, and fiberglass. Processed mineral fibers, ceramic fibers, and other unspecified fibers may also be included in the formulations. Carbon fibers are used in some industrial friction products applications and in airplane brakes. Research on the use of other fibers such as calcium sodium metaphosphate and attapulgate is in progress.*

A. Manufacturing Process

Most friction products may be manufactured using either a wet-mix or a dry-mix process.+ These processes may vary by manufacturer, raw materials used, and product, but the basic steps are as follows:

Wet-mix process:

- Mixing of fibers, resins, property modifiers, and solvents;
- Extrusion or rolling;
- Molding and curing using heat and pressure; and
- Finishing by grinding and drilling.

Dry-mix process:

- Mixing of fibers, resins, and property modifiers;
- Molding and curing using heat and pressure; and
- Finishing by grinding and drilling.

*ICF Inc., "Substitution Analysis for Asbestos Brake Linings for On-Road Vehicles," May 1, 1985, p. 17.

+ Woven band friction products are not discussed here; manufacturing processes are similar to those discussed for woven products in Section V, Textile Products.

The wet-mix process is usually used for automobile drum brake linings, while the dry-mix process is usually used for disc brake pads, truck brake blocks, and heavy duty friction materials. Clutch materials are produced by both methods.* In both processes there may be several steps to the molding and curing process, and procedures required for finishing may vary.

The mixing process basically consists of blending all raw materials, which may include from six to two dozen ingredients, according to a representative of Carlisle, in a mixer with rotating blades. Aramid fibers generally require opening or fluffing for uniform mixing because aramid fibers have a tendency to clump together during mixing.+ The fluffing is generally done in the mixer, with other ingredients added after fluffing, although some companies might use a separate process for fluffing (Carlisle).

Details of the manufacturing process and level of automation vary from manufacturer to manufacturer. In the production process, bags of raw materials may be opened by machine and carried by conveyor belt to the mixer, or the bag opening and dumping may be done manually. Carlisle claims bag opening by machine may not be practical because machines usually open only one size bag. Materials may be carted by hand from one process step to another or they may be moved automatically. While machines carry out each step in the manufacturing process, workers operate the machines. Friction products must meet specifications, which necessitates checking the machine products frequently and adjusting the machinery as necessary, according to the Carlisle representative.

* Nancy Krusell and David Cogley, "Asbestos Substitute Performance Analysis," February 1982.

+ DuPont, "Kevlar® A Reinforcing Fiber Substitute for Asbestos," 1985. Product literature.

There appears to be considerable variation in the degree of automation within the friction products industry. Bendix, one of the largest companies, is not highly automated; materials are hand-carried between process steps. At the Delco Moraine Division of General Motors, which produces semi-metallic automobile disc brake pads, the fiber and resin mixture, produced in a computerized mixing room, is put into a machine which carries out all the molding, curing, and finishing steps and attaches the pads to the brake shoes. Some types of friction products may require more careful handling than others, and, therefore, the manufacturing process may be more labor intensive. For example, drum brake linings, because of their arc-shape, may tangle, and have to be piled carefully, according to a Bendix representative. Disc brake pads are simpler in shape and are probably easier to handle.

B. Potential Exposures and Controls

Carlisle claims friction products manufacturing produces large quantities of dust. We have no information about the quantity or the fiber content of the dust. In general, Carlisle claims that the friction products industry is very concerned with possible hazards because of its experience with asbestos. Dust-capturing equipment is usually used, and all companies have safety engineers (according to a Carlisle engineer).

Many friction product companies produce substitute products in the same plant as asbestos products, often using the same equipment. Equipment used by Carlisle and Bendix includes dust-catching equipment consisting of exhaust hoods with strong suction over every processing step. Respirators are available, though not required for non-asbestos workers. Air monitoring for asbestos is carried out in plants producing both asbestos and non-asbestos products; however, Carlisle says that there is no monitoring specifically for

other fibers. There is usually frequent vacuuming of the floors of plants. When new equipment is set up for non-asbestos products, Bendix says dust-capturing equipment is installed as needed.

Durawool, a company which supplies steel wool fibers to friction product manufacturers, believes that semi-metallic friction product producers who use steel wool fibers probably have fewer controls than producers using other fibers. Durawool reports that workers who handle steel wool fibers wear gloves, but it is the company's feeling that steel wool fibers are too heavy to become airborne (no data was given to support this claim).

Dupont provided monitoring data of airborne dust levels at a friction product manufacturing plant. This plant belongs to one of Dupont's customers and was monitored by DuPont in 1982. Seventeen samples were taken and the results showed a range of airborne fiber concentrations from 0.01 to 0.07 fibers per cubic centimeter (cc) of air. The maximum likely eight-hour time weighted average (TWA) exposure is less than 0.1 fibers per cc. Dupont has suggested a workplace exposure limit of 5 fibers per cc (8-hour TWA) to its customers.

C. Fiber Sizes

A number of fibers are used as asbestos substitutes in friction products. Table 5 presents the dimensions of fibers which may be used in friction products. Because formulations are proprietary, it is difficult to determine which fibers are in use; some fibers listed in Table 6 may not be used currently, while there may be other fibers currently used in some friction products that are not listed. The size of the fiber may depend on the formulation used by the manufacturer. For example, four grades of steel wool (grades 0, 1, 2, and 3) are used in friction products, according to Durawool. The range of fiber diameters shown in Table 5 is the range from Grade 0 (12.7

Table 6. Dimensions of Fibers Used in Friction Products

| Fiber Type | Length (microns) | Diameter (microns) | Aspect Ratio (length/diameter) |
|--------------------------|------------------------------|-----------------------|-----------------------------------|
| Steel Wool (Grades 0-3) | 800-2,000 | 13-114 ^a | 7-157 |
| Aramid (Short Fibers) | 6,000 or 12,000 ^b | 12 ^c | 500 or 1,000 |
| Aramid (Pulp) | 2,000 or 4,000 ^b | 12 ^c | 167 or 333 |
| Fiberglass | 3,175+ | 13 | 240+ |
| Mineral Fiber | 28 | 1-10 | 40-60 |
| Ceramic Fiber (Chopped) | 305 | 2 | 150 |
| Wollastonite | - | - | 15 |
| Calcium Sulfate Whiskers | 50+ | 2 | 25+ |
| Graphite | 6,350+ | 8.4 | 750+ |
| Carbon | 6,350+ | 11 | 575+ |
| Cellulose | 76 | 18 | 4 |

^a

Durawool, Queens Village, NY, telephone conversation with Mr. Neustadler, May 21, 1985.

^b

DuPont, "Kevlar® A Reinforcing Fiber Substitute for Asbestos," 1985. Product literature.

^c

JRB Associates, "Data Summaries and Hazard Assessments for Asbestos Substitutes," January 11, 1985.

Source: Michael G. Jacko, Charles F. Brunhofer, and F. William Aldrich, "Non-Asbestos Friction Materials," in Proceedings of the National Workshop on Substitutes for Asbestos, November, 1980, p. 17.

to 38.1 microns) to Grade 3 (88.9 to 114.3 microns). Fibers of the desired grade are cut to the length requested by the product manufacturer. According to product literature from DuPont, aramid fibers for friction products are available as short fibers in two lengths (1/4-inch and 1/2-inch) or as pulp with highly fibrillated fibers, also in two lengths (0.08-inch and 0.16-inch).

Exposure data and fiber size distributions of airborne fibers were not found. We do not know how input fiber sizes reported relate to airborne fiber sizes.

D. Industry Contacts

The following industry sources provided information on friction products during May 1985:

1. Bendix, Friction Materials Division
Gene Rogers
Environmental Department
Troy, New York
2. Carlisle Motion Control Industries
Research and Development Engineer
Ridgway, Pennsylvania
3. Delco Moraine Division of General Motors
Jim Sayer
Manager of Market Development
Dayton, Ohio
4. Durawool
Mr. Neustadler
Queens Village, New York
5. Nuturn
Euan Parker
Smithville, Tennessee
6. Scan-Pac
Wisconsin

IV. LIQUID PRODUCTS

This product category includes liquid products such as roofing and flashing cement, automobile undercoatings and sealants, caulks and sealants, roof coatings, pipe coating, and chemically resistant coatings and linings. The most important application of asbestos in liquid products is roof coatings. Potential fiber replacements for asbestos in these products include fiberglass, cellulose, acrylics, nylon, and polyethylene/polypropylene.

A. Manufacturing Process and Emission Controls

The manufacturing process for liquid products has the following steps:

- Fiber introduction;
- Wet mixing; and
- Packaging.

In the manufacture of roof coatings, 50 pound bags of fiber are delivered to the plant on pallets carrying 20 to 30 bags. The bags are manually opened with a knife and are dumped into the mixer. The solvents, asphalt, and other liquid ingredients are fed to the mixer automatically. Tremco indicated that they design mix quantities to accommodate multiples of 50 pound quantities of the fiber so that no partially used bags of fibers are left in the workplace. They dispose of all empty bags in closed containers. Once the fibers and liquids are well blended, the mixture is pumped automatically to the packaging area where it is automatically drummed. An operator is needed to manually put lids on the drums after they are filled.

Tremco says that the bag openers in its facility wear coveralls, gloves, and masks. Tremco reports that it has an exhaust ventilation system that effectively controls fiber exposure. Fibers are collected and disposed using a closed ventilation system. Substitute fibers are handled the same way they used to handle asbestos. As an added precaution, Tremco also provides yearly physical examinations to check the lung capacities of its employees.

Gibson-Homans supported the information provided by Tremco. Gibson-Homans also has ventilation over the mixing vessel, and the bag feeder wears a dust mask and gloves (estimated 99 percent of the time). There appears to be little variation in the roof coatings industry.

B. Potential Fiber Exposure

Fiber exposure is possible during the manual fiber feed and during the mixing process. Once the fiber is encapsulated, fiber exposures may not be a concern.

The labor force exposed in a roof coatings plant is quite small, between 2 to 4 people per line split between the bag feeding and product packaging areas (Tremco, Gibson-Homans). These operations are not continuous around the clock. Typically, only one shift is operated in the winter, 2 shifts during the spring and fall, and three shifts during the summer (Tremco).

C. Fiber Sizes

The fiber mixtures used by roof coating manufacturers are considered proprietary information. Fiber mixtures are often required to get the same properties as asbestos. The specific fiber size is specific to the final product application. The substitute fiber blend and fiber sizes must be designed by trial and error for each product; the key processing factor is to get the desired oil absorption by the fiber. High oil absorption is desired so that the coating does not flow during its lifetime. Gibson-Homans said its fibers are typically 1/4-inch or less in length. Information on fiber diameter was not available since manufacturers contacted claimed this information to be proprietary.

Hercules says that Pulpex® (polyethylene and polypropylene types) fibers for coatings are approximately 1 mm in length and 20 to 40 microns in diameter. There is a bell-shaped distribution of fiber lengths and diameters around these nominal values in the Pulpex® pulp. The JRB report prepared for EPA* indicated wet lap, wet fluff, and dry fluff grades for Pulpex fibers; average length ranged from 0.6-1.2 mm, with maximum length at 2.0-2.5 mm and diameters of 10-40 microns.

D. Industry Contacts

The following is a list of the industry sources contacted concerning liquid products during May 1985:

1. Celotex Roofing Products
David Gluck
Department Manager
St. Petersburg, Florida
2. Dudick Corrosion-Proof Manufacturing
Ron Kurta
Macedonia, Ohio
3. Gibson-Homans
Bob Kirkpatrick
Quality Control and Formulations
Twinsburg, Ohio
4. Hercules Corporation
Bob Ruse
Project Manager, Pulpex Fiber
Wilmington, Delaware
5. Tremco
Ken Brozowski
Director of Research
Cleveland, Ohio

* JRB Associates, Data Summaries and Hazard Assessments of Asbestos Substitutes, January 11, 1985.

V. TEXTILE PRODUCTS

Potential durable fiber substitutes for textiles include fiberglass, polybenzimidazole, phenol-formaldehyde polymer, aramid, ceramic, silica, polyester, and acrylic fibers.

A. Manufacturing Process and Controls

The conventional textile-making process involves fiber blending, mixing, and carding. Carding essentially combs the fibers into a relatively parallel arrangement called a fiber mat. This spider-web-like mat can be needle-punched to form a felt-like textile or pressed to make a batting-type material, which is woven/folded for use as an insulating-type textile. If the (spider-web-like) mat is run through a nozzle, it produces a loose, round "sliver" approximately one inch in diameter. The sliver is then processed by "drawing", and the drawn product (referred to as a "drawing sliver" as opposed to a "carding sliver") is a much smaller-diameter product called roving, which is similar in diameter to a pencil. The roving can be spun into a very coarse or very fine yarn (Celanese Plastics and Specialties, AmateX Corporation). Single yarns can be woven, twisted, or braided and can be specially coated; un-spun roving may also be twisted and/or braided to make rope. The asbestos textile products are threads, yarns, woven products (tape, cloth, and tubing) and braided products (tubing, cord, and rope).

Another manufacturing process for textile products which replace asbestos textiles uses continuous filaments of either fiberglass (produced by a company such as Owens-Corning or PPG) or carbon/graphite such as that produced by Garlock or Celanese Plastics and Specialties which can be twisted together to form yarns which are then spun into textiles. Glass filaments are usually coated with a starch-like resin "sizing" which aids in the weaving process and produces a textile with a smoother finish; the glass would otherwise have a

rougher surface. This sizing is generally burned off the finished textile surface in an infrared oven (Amatex Corp). Carbon fiber filaments are also generally coated (Hercules Corporation).

B. Fiber Sizes

The conventional-type process uses standard-length fibers, approximately 1-1/2", the standard cotton fiber-length. Fibers must all be approximately the same size for the carding process, as longer fibers are difficult to card (tend to break) and shorter fibers have a tendency to fall away and do not exhibit the same strength characteristics as longer fibers. For the last two years, Owens-Corning has been marketing a "cardable glass fiber" which is the standard 1-1/2" textile fiber length. At the present time, a representative of Amatex believed that his company was the only company other than Owens-Corning developing a product line using this cardable fiberglass. Apparently, cardable fiberglass is difficult to card and the glass fibers tend to break in the carding process. A product specialist at Owens-Corning did not believe breaking was a problem but noted that even if it were, fiber diameter would still be larger than that of asbestos (data was not supplied to support this claim). The advantage to the traditional carding-type textile manufacturing process in substitute fibers is that the textile can be engineered towards end-use by creating "hybrid" fiber mixes which take advantage of fiber-specific properties of a variety of fibers (Amatex). A product specialist from Owens-Corning indicated that cardable glass fibers are handled in strand form, with several hundred filaments to each strand. Varying filament diameters are available, but the typical diameter used for asbestos replacement was 6 microns ("DE" type fiberglass) and typical strand length was 2 inches for asbestos replacement.

The continuous filaments of fiberglass have varying diameters. Owens-Corning and PPG offer fiberglass continuous filaments in diameters from 3 to 13 microns. The finest continuous filament commercially available has a diameter of about 3.5 microns. This product is produced in relatively small quantities. Most continuous filament fiberglass has a diameter of 9 microns or larger.* (See Section II.C for a discussion of the distribution of airborne glass fiber diameters found in occupational environments.)

DuPont product literature for Kevlar® indicated that staple length fibers were available (lengths from 1-1/2 inches to 4-inches).

The fiber sizes presented here are input fiber sizes; they are not meant to represent airborne fiber sizes. Fiber input sizes for polybenzimidazole, phenol-formaldehyde, ceramic, silica, polyester, and acrylic fibers were not obtained.

C. Exposure to Fibers

As previously noted, the carding of glass fibers can cause them to fragment into smaller fiber fragments which may become airborne.

Newtex Industries weaves aluminized glass fiber products from continuous filament fiberglass. A representative of Newtex thought there was ventilation above the looms with one or two operators at each loom. The braiding and taping rooms (making rope and tape) are probably not ventilated, and usually one or two operators work in each room. The representative indicated that glass fibers were present in the air during operation.

A representative from Amatex Corporation indicated that a "typical" blending/carding textile manufacturing line would require 2 or 3 operators;

* Jon L. Konzen, M.D., "Man-Made Mineral Fibers - Their Health Effects," p. 3. Presented at the Conference on Environmental Toxicology, Dayton, Ohio, November 13-15, 1979.

one for blending and mixing, and one for carding. The fiber mix would be dry and might use a Banbury-type mixer. The representative believed that a "typical" continuous filament manufacturing line would require 4 or 5 operators and would produce a higher volume of textiles than a carding process, such that 2 or 3 operators on either line produced the same volume. He indicated that no ventilation would typically be required or present for either production line.

Emissions data were available for one textile operation using 3M's Nextel 312 Ceramic fibers (continuous filaments with 11 micron diameter). The results are shown in Table 7.

D. Industry Contacts

The following industry contacts provided information on textile products during May 1985:

1. Amatex Corp.
Durable Fiber Textiles
Joe Broderick
Asst. Plant Manager
Norristown, PA
2. Celanese Plastics and Specialties
Polybenzimidazole Fiber
Bob Lowry
Product Specialist
Charlotte, NC
3. Newtex Industries
Aluminized Glass Fiber Textiles
Mr. Sarat
Technical Representative
Victor, NY
4. Owens-Corning
Cardable Glass Fibers
Peter Rowman
Product Specialist
Toledo, OH

Table 7. Emissions Data: Textile Production with
3M's Nextel 312 Ceramic Fibers (Personal Samples)

| Operations | Concentration (Number Fibers/cc Air) | Number Fibers on Filter | Fiber Sizes (u) | |
|-----------------|---|----------------------------|-----------------|----------|
| | | | Length | Diameter |
| 1. Serving | 0.00004 | 6 | 120 | 13.5 |
| | | | 192 | 8.1 |
| | | | 216 | 8.1 |
| | | | 264 | 8.1 |
| | | | 300 | 10.8 |
| | | | 300 | 10.8 |
| 2. Serving | 0.00001 | 2 | 108 | 10.8 |
| | | | 792 | 10.8 |
| 3. Core Winding | 0.000007 | 1 | 120 | 8.1 |
| 4. Weaving | 0.00005 | 8 | 151 | 10.8 |
| | | | 180 | 10.8 |
| | | | 215 | 10.8 |
| | | | 229 | 10.8 |
| | | | 264 | 8.1 |
| | | | 300 | 8.1 |
| | | | 324 | 9.5 |
| Mean | 0.00004 | 4.25 | 360 | 10.8 |
| | | | 261 | 10 |

Source: Environmental Protection Agency, Office of Pesticides and Toxic Substances. "Proceedings of the National Workshop on Substitutes for Asbestos," November, 1980, p. 438.

VI. ROLLED PRODUCTS

Rolled products include compressed sheet gaskets, packings, and fiber-reinforced vinyl floor tile. Potential durable fiber replacements for asbestos in rolled products include fiberglass, acrylic, aramid, cellulose, ceramic, graphite, polyethylene/polypropylene, silica, and teflon fibers.

A. Manufacturing Processes and Variation

The basic manufacturing process for products referred to as "rolled products" is a batch, wet or dry mixing of raw materials (fiber, elastomeric/other binder, and solvent) to obtain a dispersed agglomerated mass. The mass is then transferred to a series of rollers (which may be heated), and the process becomes essentially continuous. The raw material is squeezed down to a desired thickness, calendered to the appropriate width, and cut to the desired size and shape.

Two industry sources provided information on manufacturing processes and controls for compressed sheet gaskets. One source provided information on fiber-reinforced vinyl floor tile.

Both industry sources producing compressed sheet gaskets (Victor Products Division and Garlock, Inc.) produce both aramid and asbestos products using a wet mix process and treat the two fibers in an essentially identical manner. However, at Victor Products Division, fiber bags are manually opened and emptied into the mixer; whereas at Garlock, fiber bag opening and feeding is automatic. The only operator interaction at Garlock is the loading of plastic-enclosed bales of fiber onto a conveyor; the process at Garlock is a completely closed system from beginning to end. Victor Products Division's process required manual emptying of mixers onto a conveyor which carried the mix to the closed calendering process.

The industry source (Monsanto) providing information on fiber-reinforced vinyl floor tile indicated that asbestos was formerly added to vinyl floor tiles to provide dimensional stability. The Monsanto representative said, to his knowledge, only one U.S. floor tile producer purchased Monsanto's Santoweb fibers (coated cellulosic fibers) for vinyl floor tile reinforcement. Other U.S. floor tile producers used proprietary methods which do not require fiber addition to provide dimensional stability. Santoweb was specifically developed for use in reinforcing floor tile (and is heavily used outside the U.S.).

As far as the Santoweb fiber product representative knew, the manufacturing process for reinforced vinyl floor tiles utilized a Banbury Mixer (internal high shear mixer). The mixer would be filled through a hole in the top (which was closed during mixing) and would be emptied through the bottom. He was not aware of the exact formulation for the tiles and could not say whether a dry mix was first accomplished with later addition of wet materials or whether the mix was wet from the start.

B. Fiber Sizes

The Santoweb fibers, as previously noted, were specially developed for use in floor tile reinforcement. They average 1.5 millimeter in length with a "bell-shaped" length distribution (because they are wood pulp, the size distribution is somewhat wide). Average length to diameter ratio (average aspect ratio) is greater than 100.

No fiber size data was available for other potential durable fiber replacements or for compressed sheet gaskets.

C. Exposure to Fibers and Controls

Victor Products Division's manual de-bagging and fiber emptying processes for compressed sheet gaskets generally involve one operator per batch. This

one operator is capable of running several mixers at once because his involvement halts during mixing. Hoods are used in the plant (mostly for solvent fumes mitigation, according to the Materials Manager/Engineer) and masks are available. Masks are required to be worn by operators on lines using asbestos, but not for those using other fibers.

Garlock's operation requires one operator to load bales and one operator to remove finished products from the completely closed, automatic line. A third operator mans the control room.

Dupont monitored airborne dust levels at one of its customers' plants in 1982. The plant manufactures compressed sheet gasketing material. The maximum fiber count of the five samples taken was 0.09 fibers per cubic centimeter (cc) of air; the average fiber count was 0.05 fibers per cc. The maximum likely eight-hour time weighted average (TWA) exposure is less than 0.1 fibers per cc. Dupont has recommended to its customers an exposure limit of 5 fibers per cc for an eight-hour TWA.

D. Industry Contacts

The following industry contacts provided information on rolled products during May 1985:

1. Monsanto
Santoweb Fiber (for reinforced vinyl floor tile)
David Taylor
Product Representative
St. Louis, MO
2. Victor Products Division
Compressed Sheet Gaskets
Kanu Shah
Materials Manager/Engineer
Lisle, IL
3. Garlock, Inc.
Compressed Sheet Gaskets
David Lingard
Engineer
Palmyra, NY

VII. ASBESTOS-CEMENT SUBSTITUTE PRODUCTS

Two approaches to replacing asbestos in asbestos-cement sheet have been to replace the asbestos fiber with a different kind of fiber reinforcement, or to substitute an entirely different sheet material for the asbestos-cement sheet. Currently, the Manville Corporation is the sole U.S. manufacturer of an asbestos-free cement sheet which is reinforced with a fiber substitute. Depending on the application, other sheet materials (i.e., laminated hardboard, alumina-silica products, and cement/wood board) are available as asbestos-cement sheet substitutes, however, fibers are not incorporated into the manufacturing processes of these products. Fiberglass was the only durable fiber substitute for asbestos in asbestos-cement sheet identified in ICF's earlier work. However, it appears that an organic fiber blend may also be used.

A. Manufacturing Process

In the production of asbestos-free cement sheet, the Manville Corporation substitutes an organic fiber blend for the asbestos fiber. Because the information was considered proprietary, information regarding the exact composition of the fiber blend, the fiber size distribution, or the specific manufacturing processes was not available. However, a company spokesman for Manville Building Products described the process as being similar to a wet-mechanical process used for manufacturing asbestos-cement sheet. The wet-mechanical process is similar in principle to a papermaking process (Figure 3). Asbestos fiber or a substitute fiber is combined with cement, silica, and other filler material in a dry mixer and is then transferred to a wet mixer. There, the dry materials are mixed with water to form a slurry which is pumped to cylindrical vats for deposition onto one or more screen

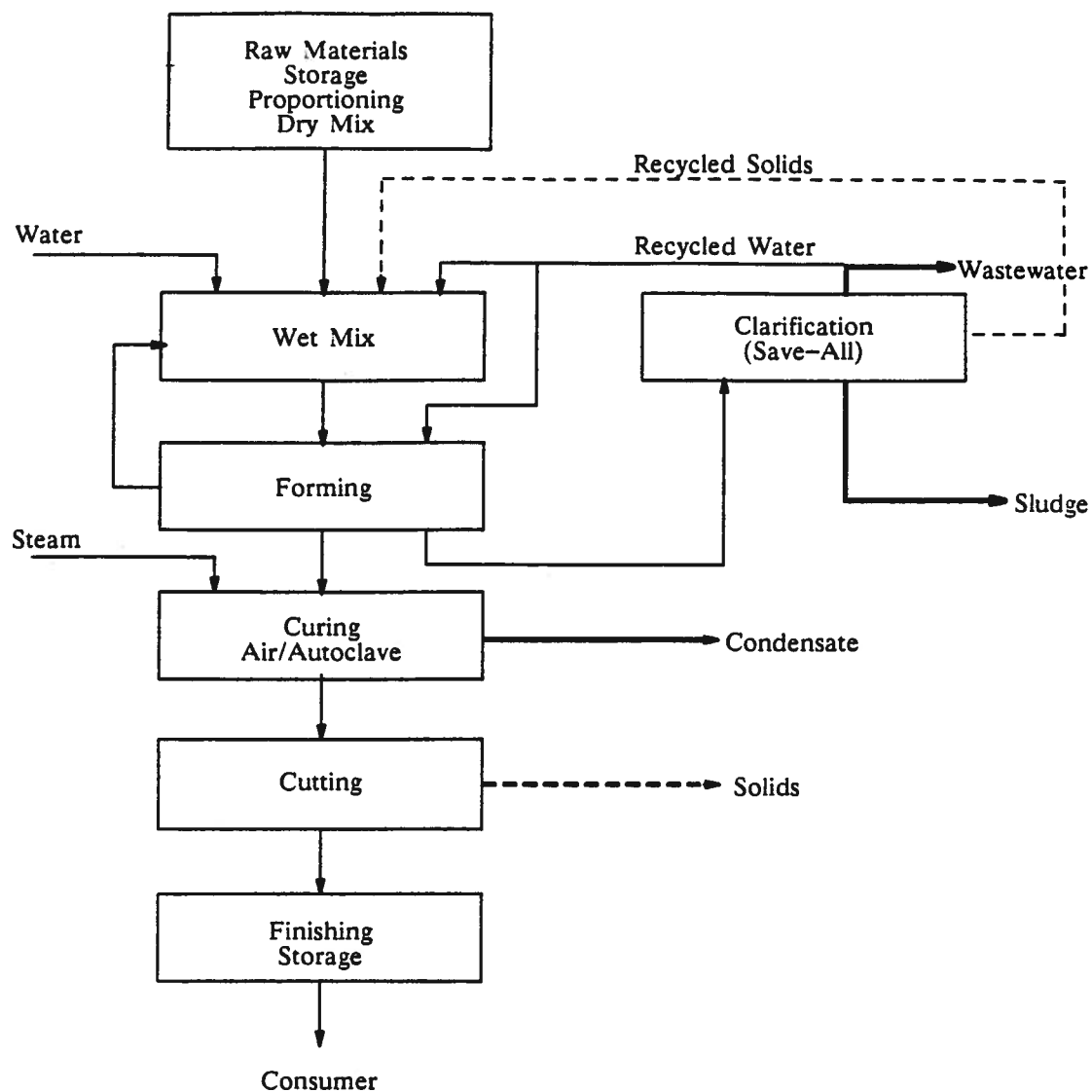


Figure 3. Asbestos-cement sheet manufacturing operations, wet mechanical process.

cylinders. A layer of sheet material is produced by this process, and a mat is built up by subsequent layering. The resultant sheet of desired thickness can be shaped or molded by hand or by a press roller.

B. Potential Exposures and Controls

Presently the Manville Corporation's policy is to treat the organic fiber blend substitute as if it were asbestos. Therefore, appropriate controls to reduce or eliminate potential exposures are incorporated into the manufacturing process. The dry mixing and the cutting and molding areas pose the greatest threat for potential exposures. In these areas, personnel protection devices such as respirators and adequate dilution and exhaust ventilation are provided. The company monitors routinely for fiber exposures, although data was not readily available. In addition because the majority of the process is a wet process, concern for generating airborne fibers was considered minimal by Manville (monitoring data was not available to support this claim).

C. Variation Within the Industry

In contrast, the Cem-Fil Corp. in Nashville, Tennessee offers a glass-reinforced cement sheet which is produced in Great Britain by its parent company. The manufacturing process, which is also a wet process similar to that used by Manville, substitutes fiberglass for asbestos fibers. Depending on the final product, the fibers used are from 3,175 microns (.125 inches) to 38,100 microns (1.5 inches) in length and 13 microns in diameter. Because fiberglass is considered a nuisance dust, no personnel protection is required. However the company does supply disposable respirators in the cutting and grinding areas. General ventilation is also provided.

D. Industry Contacts

The following is a list of the industry sources contacted concerning asbestos-cement-substitute products during May 1985:

1. Cem-FIL Corporation
John-Jones
Nashville, Tennessee
2. H.H. Robertson
Resolite Division
Pennsylvania
3. Manville Corporation
Tony Mann
Waukegon, Illinois

VIII. REINFORCED PLASTIC MOLDING COMPOUNDS

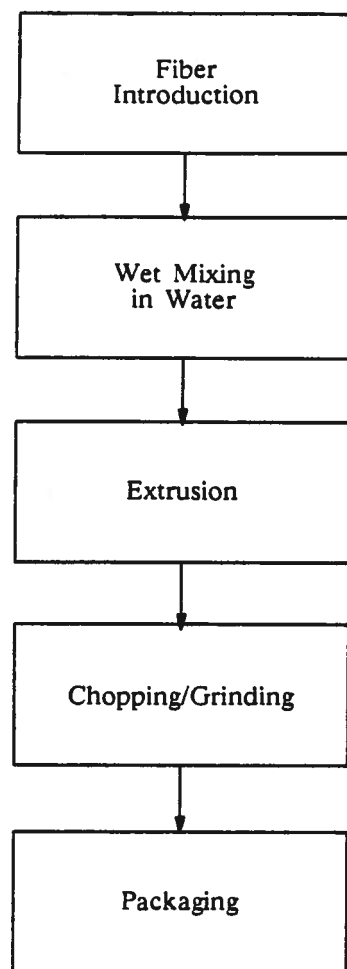
This product category includes pelletized (and granular) products for reinforced plastics, the most important of which are phenolic molding compounds. Potential durable fiber replacements for asbestos in these products include fiberglass, carbon fibers, aramids, processed mineral fibers, and wollastonite.

A. Manufacturing Process and Emission Controls

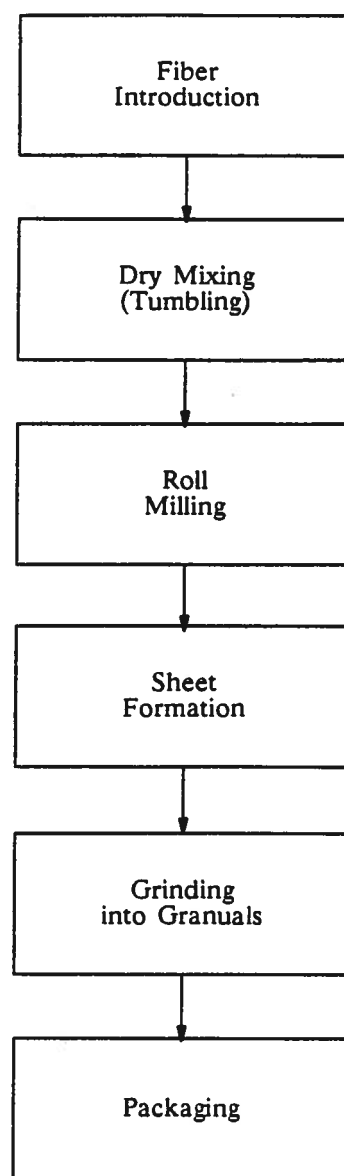
Rogers Corporation produces phenolic molding compounds. The process is shown in Figure 4(a). The fiber is delivered in 50 pound cardboard containers which are manually opened and emptied into the mixer where it is wet-mixed with dry resin and fillers in a water medium. The liquid mixture is then automatically transferred to an extruder where the resin melts, encapsulating the fiber, and is extruded to form pellets or sheets, which are later ground into granuals. Prior to any cutting or grinding, the extruded product is dried to remove the water that had been used as the wet-mix medium. The finished product is automatically transferred to containers which must be manually closed.

Ventilation hoods which lead to dust collection devices are used in this phenolic molding compound facility wherever dusting may occur. Work uniforms are provided and are laundered by Rogers daily. Employees wear gloves to protect from sharp edged materials, and respirators are provided. The operations manager of Rogers Corporation said that employees use the respirators a good percentage of the time, but not 100 percent of the time.

Rogers described another process used for the manufacture of phenolic molding compounds which is quite different from the one described above (see Figure 4(b)). The fibers, fillers, and dry resin are tumbled together to create a dry mix. This dry mixture is forced through a roll mill which



(a)



(b)

Figure 4. Reinforced plastic molding compound production processes.

consists of two steel rollers at different temperatures and moving at different speeds. These rollers rotate towards each other creating a nip, a small space through which the dry mix passes. The friction and temperature differential cause the resin to melt thus encapsulating the fiber. The resin mixture leaves the roll mill in a sheet form. This sheet is then cooled and ground. No indication of the percentage of the industry using this process was provided.

B. Potential Fiber Exposure

Fiber exposure is possible during the manual fiber feed and during the mixing process. Once the fiber is encapsulated, fiber exposures may not be a concern. The roll mill process used to make phenolic molding compounds may allow for added exposure potential since it is a dry-mix process. Rogers says that some fly (airborne fibers) is noticeable, but it is like what you might see in your home when a sunbeam shines through a window. This level of fly is believed by Rogers to be well below the nuisance dust levels (exposure monitoring data was not provided to support this claim).

Rogers provided information on the labor force of its entire facility. Approximately 100 people work at the plant of which 15 work with the raw materials. This data may be for more than one operating line.

C. Fiber Sizes

For phenolic molding compounds, the appropriate fiber and fiber size depends on the application. The general answer is "fiberglass". However, the fiberglass must be blended with a variety of fibers and fillers to match the properties of asbestos. Rogers has blended fiberglass with organics (nylon, polyethylene terephthalate, or orlon), inorganics with aspect ratios (processed mineral fiber or Wollastonite), and inorganics without aspect ratios (clay or mica). For molding compounds, a fiber which provides flow

capabilities is needed. Typically a chopped fiberglass of length between 1/8 and 1/4-inch is used. The most common fiber diameters are 10 microns and 13 microns. Occasionally diameters as small as 4 microns and 6 microns will be used. The fiber lengths will sometimes be reduced to even less than 1/8-inch during compounding, but the aspect ratio is always greater than 100. Fiber breakage may occur as the resin/fiber mixture is extruded (forced through the screw and die plate) or when the dry-mix resin/fiber is passed through the roll mill.

Some information was obtained from fiber manufacturers concerning the appropriate fiber sizes to be used in these products. Certain-Teed recommends a fiber length of 1/8 to 1/4-inch for chopped fiberglass to be used as plastic reinforcement. Certain-Teed sells "chopped strand" fiberglass fibers in lengths of 1/8-inch, 3/16-inch, and 1/4-inch, with a 14 micron diameter specified for use with thermoset resins. Fiber size input for use with thermoplastic resins was not specified in the product literature. (See Section II.C for a discussion of the distribution of airborne glass fiber diameters found in occupational environments.)

Wollastonite may also be used to replace asbestos in reinforced plastics. Fiber diameter is 3.5 microns and fiber lengths are between 10.5 and 70 microns. Processed mineral fiber having 4 to 6 micron diameter and 160 to 360 micron length and Franklin Fiber (crystalline calcium sulfate) having 4 to 6 micron diameter and 400 to 600 micron length are also possible substitutes in reinforced plastics.*

* Matthew Naitove, "Asbestos in Plastics: Looking for Alternatives," presented at the National Workshop on Substitutes for Asbestos Sponsored by EPA, CPSC, and the Interagency Liaison Group, pp. 61 and 64 of the Proceedings, November 1980.

Data for carbon and graphite fibers was provided by Union Carbide, Hercules, and Celanese. Union Carbide sells its fibers in reels. They will cut the fibers to 1/4-inch length if the customer desires. These fibers are small bundles of filaments ranging from as low as 1000 filaments/fiber to 12,000 filaments/fiber. The fibers are coated with sizing before sale to allow for better mixing with resins. A low modulus carbon fiber is used for reinforced plastics. Since the fiber is to be chopped, the 12,000 filament/fiber product is recommended. This fiber has a diameter of 0.76 mm, but each filament has a diameter of 7 microns. It is recommended that these carbon fibers be handled as little as possible. They will not break when chopped; however, there will be some fly (airborne fibers) during chopping. Union Carbide sells other grades of carbon fibers with diameters ranging from 6 microns to 11 microns.

Hercules also sells continuous filament graphite fibers in both 5 and 8 micron fiber diameters. The filaments are bundled (3,000, 6,000, or 12,000 filaments per fiber) into fibers similar to Union Carbide's products. A coating is applied to hold the filaments together and to reduce fly during chopping. Hercules confirmed the 1/4-inch chopped fiber length as being the shortest standard length for carbon fibers in reinforced plastics.

Celion Corporation (formerly Celanese Plastics and Specialties) Product Literature confirmed the 1/4-inch standard length for carbon fibers used for plastics reinforcement, with available filament diameters being 6.6, 7.0, and 8.4 microns.

DuPont product literature for Kevlar® recommends chopped fiber lengths of 1/4-inch or 1/2-inch for use in reinforced plastics.

Fiber size inputs were available for all substitute durable fibers used in reinforced plastics. Table 8 summarizes fiber dimensions used in reinforced

Table 8. Dimensions of Fibers Used in Reinforced Plastic Molding Compounds

| Fiber Type | Length (microns) | Diameter (microns) |
|-------------------------|--------------------------------|-----------------------|
| Fiberglass | 3,175-6,350 (0.125 in-0.25 in) | 10-13 |
| Wollastonite | 10.5-70.0 | 3.5 |
| Processed Mineral Fiber | 160-360 | 4-6 |
| Carbon Fiber | 6,350 (0.25 in) | 6.6-8.4 |
| Graphite Fiber | 6,350 (0.25 in) | 5-8 |

Source: Industry Contacts, May-June 1985 and Product Literature.

plastic molding compounds. However, no indication of airborne fiber sizes was provided.

D. Industry Contacts

The following is a list of the industry sources contacted concerning reinforced plastic molding compounds during May 1985:

1. Celanese Plastics and Specialities
Jim Lewis
Chatam, New Jersey
2. Certain-Teed Corporation
Customer Inquiries Department
Valley Forge, Pennsylvania
3. DuPont, Haskell Laboratory
Mike Hawkins
Wilmington, Delaware
4. Hercules Corporation
Roger Sterling
Sales Representative
Utah
5. Rogers Corporation
Ray Mikulak
Operations Manager
Manchester, Connecticut
6. Union Carbide, Carbon Products Division
Patty Erichs
Sales Representative
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PART B

POTENTIAL FIBER EXPOSURE DURING SECONDARY PRODUCT
MANUFACTURE AND POST-MANUFACTURE USE

IX. FRICITION PRODUCTS -- POST-MANUFACTURE HANDLING AND USE

A. Introduction

This section focuses on brake linings as they are the largest-volume friction product and the one most likely to involve possible exposure to fiber in post-manufacture handling and use. Types of brake linings include:

- Drum brake linings and disc brake pads for passenger cars and light trucks;
- Brake blocks for heavy vehicles (disc brake pads are also used, but rarely); and
- Band brakes (woven) and brake blocks for industrial equipment.

A drum brake consists of a hollow metal cylinder which rotates with the vehicle's wheel. Inside this cylinder, or drum, are two pieces of metal which are curved to align with the inside of the drum. Each piece of metal, or shoe, is lined with friction material called the brake lining or, for heavy vehicles, the brake block. When the driver steps on the brake pedal, a hydraulic signal is relayed to the brake shoes which are pushed outwards against the inside of the drum. The friction created between the stationary brake shoes and the rotating drum then slows or stops the vehicle.

The disc brake consists of two pieces of metal which straddle the rotor, or disc, in the center of the vehicle's wheel. Each metal piece is lined with friction material called a brake pad or lining. When the brake pedal is depressed, the pads move inward until they touch the disc on each side. The friction created then slows or stops the vehicle. The disc brake system is not enclosed in a drum, and the brake pad is flat.

During use, the lining material is exposed to heat, pressure, and mechanical abrasion. All types of brake linings generate a certain amount of dust from wear. According to a representative of Bendix, most fiber becomes

granular as it wears; the dust from brake wear would not contain any fiber, he claimed. There have been no studies on the fiber content of dust from non-asbestos brake linings. A study of brake dust from asbestos brake linings showed that most fibers were shorter than 0.4 μm .^{*} Dust from wear may be collected in the drum, in the case of drum brakes (a certain amount may also be released into the air); released into the outdoor air, in the case of disc brakes; or released into the air in the workplace to some extent, in the case of industrial friction materials used indoors. Data on the quantity or content of dust produced by wear of non-asbestos friction materials are not available.

Each type of brake lining and possible areas of exposure to fiber during handling or use of these materials following manufacture is discussed below.

B. Brake Linings for Cars and Light Trucks

The major non-asbestos fiber used for brake linings in cars and light trucks is steel wool, used in semi-metallic disc brake pads. Some aramid is used, both for disc brake pads and drum brake linings, and small amounts of fiberglass and other fibers may also be used. Currently, most new cars are equipped with semi-metallic front disc brake pads and asbestos rear drum brake linings. Older cars may have asbestos drum brake linings on both front and rear. A small number of cars have aramid-based brake linings as original equipment.

^{*} Arthur N. Rohl, Arthur M. Langer, Mary S. Wolf, and Irving Weisman, "Asbestos Exposure During Brake Lining Maintenance and Repair," Environmental Research 12 (1976), p. 115.

Following their production by a friction products manufacturer, disc brake pads and drum brake linings for cars and light trucks may be handled in the following processes:

- Installation in brake assemblies for new vehicles;
- Bonding or riveting to new brake shoes and packaging for sale by air assembler;
- Removing old brake linings, cleaning brake shoes, and bonding or riveting new lining to used brake shoes by part rebuilders; and
- Replacement of used lining and shoe assembly with new or rebuilt lining and shoe assembly by mechanic or car owner.

1. Installation in New Vehicles

There appears to be little potential for fiber exposure during installation of brake linings in new vehicles. For use in original equipment, brake linings are produced to specification. There is no cutting, drilling, or grinding required for installation. The only potential exposure would be to dust remaining on the surface of the linings.

2. Bonding or Riveting by Assemblers

Assemblers do not produce friction materials; they buy brake linings from manufacturers, attach them to the brake shoes (metal plates), and package them for sale. It is unlikely that holes would be drilled or that any cutting or grinding would be carried out by assemblers, although it is possible that such operations take place occasionally. Generally, lining pieces are pre-cut or molded to size and drilled by the friction products manufacturer and are simply bonded or riveted to the brake shoe by the assembler; brake assembly is automated. The primary non-asbestos product handled by assemblers is the semi-metallic disc brake pad. The market for non-asbestos drum brake linings is currently very small; most drum brake linings handled by assemblers are

probably asbestos, and assemblers probably use the same procedures in handling both asbestos and non-asbestos materials. One assembler (EIS Division of Parker Hannifin) reports that workers wear coats, dust masks, and safety glasses; but local ventilation is not used to collect airborne dust.

3. Rebuilding Operations

Used brake shoes are frequently recycled to rebuilders, who remove the worn brake lining material, clean the shoe, and attach a new lining by bonding or riveting. According to a representative of EIS Division of Parker Hannifin, rivets are cut off by a deriveting machine and the old linings are removed; bonded linings are cut off by a shearing machine. It is likely that the plates are cleaned by the same methods used by truck brake shoe rebuilders (see truck section); that is, a blasting machine with a vacuum particle collection system is used to clean the plates. All brake rebuilding operations are automated. It is also likely that workers doing brake shoe rebuilding would wear masks, goggles, and gloves, as in truck shoe rebuilding. Local ventilation does not appear to be used during brake rebuilding. However, according to the Auto Parts Rebuilders Association, there are a large number of brake shoe rebuilders, some of them very small, and procedures may vary widely.

4. Replacement of Used Brake Linings

Worn brake linings must be replaced periodically; for passenger cars this is done, on the average, once every four years.* ICF has estimated that approximately 122 million drum brake lining pieces and approximately 81 million disc brake pads are sold annually for after-market use.+

* ICF, Inc. "Substitution Analysis for Asbestos Brake Linings for On-Road Vehicles", May 1, 1985, p. 10.

+ Ibid., p. 9.

Approximately 85 percent of new cars have semi-metallic front disc brake pads.* A large percentage of the disc brake pads for replacement are semi-metallic. - Only a small percentage of the drum brake linings for replacement are non-asbestos (primarily aramid). Worn brake linings are generally replaced with new linings of the same type, although one large auto service company (Sears) replaces asbestos drum brake linings with aramid linings when servicing brakes.

When brake linings are replaced, it is necessary to first remove the wheel. In the case of drum brakes, there is usually a large amount of dust from brake lining wear collected in the drum and on parts. In the case of disc brakes, there is much less dust because the design of this brake allows most of the dust produced to escape into the air during use. The dust must be cleaned out; the cleaning step appears to present a major fiber exposure potential because cleaning is performed manually. Cleaning procedures apparently vary.

A Sears Automotive Service mechanic reports that Sears' procedure is to spray the dust with a liquid chemical brake parts cleaner. This wets the dust, minimizing the chance for it to become airborne, and cleans the brake parts. The brake drum (in the case of drum brakes), which contains most of the dust, is removed and cleaned. Mechanics wear dust masks during the cleaning procedure, but the facilities are not locally ventilated. The worn brake shoe (lining and metal plate) is removed and discarded or returned to a rebuilder, and a new or rebuilt shoe with lining attached is installed. A service facility specializing in brakes reported procedures similar to Sears,

* ICF, op. cit., p. 27.

including use of a liquid chemical brake cleaner; however, no personal protective equipment is worn at this facility.

The owner of a full service garage, which has six mechanics and is unlikely to do more than one or two brake jobs per day (about one per week per mechanic), reported that his mechanics remove the brake drum and tap the dust into a trash can. They may then use compressed air as the most efficient way to clean out the remaining dust. They do not use any protective equipment such as masks. It is possible that some facilities use compressed air as the first step for cleaning all the dust from the brake assembly. This was standard procedure about ten years ago, and some service people, particularly in small garages which do not do large numbers of brake jobs, may still find it the quickest and easiest cleaning method. This method would, of course, expose other mechanics besides the one performing the brake job to dust from the brake lining.

C. Brake Blocks for Heavy Vehicles

Truck brake blocks (drum brake linings) of aramid fiber and fiberglass are currently in use as substitutes for asbestos. Estimates of the percent of the market held by substitutes range from 10 percent to nearly 50 percent.* A small number of trucks, probably less than one percent,+ are equipped with disc brakes; because the number is so small, we will only consider drum brake blocks in this discussion.

The processes following manufacture which may lead to fiber exposure include the following:

- Installation in new vehicles;

* ICF, op. cit., p. 19.

+ Ibid., p. 26.

- Removing old brake blocks, cleaning brake shoes, and attaching new brake blocks to used brake shoes by rebuilders; and
- Replacement of used block with new or rebuilt lining and shoe assembly.

(We found no indication that there are assemblers of truck brake blocks as there are for automobile brake linings.) No data were available on fiber exposure during any of these processes.

1. Installation in New Vehicles

As in the case of cars and light trucks, the only potential for exposure during installation of truck brake blocks in brake assemblies for new vehicles appears to be to dust remaining on the surface of the new brake block. According to one manufacturer (Carlisle), the amount of dust should be small because manufacturers clean off the dust before packaging.

2. Rebuilding Operations

Brake block rebuilding includes removing the worn brake lining from the plate, cleaning the plate, and attaching a new lining to the clean plate. As described by one rebuilder of truck brake blocks, used brake blocks are sheared off the brake shoe by a machine; the old blocks drop into a box and are not handled by workers. The brake blocks are sprayed with water before they are put into the machine if they are dusty, to minimize dust in the air. After the linings are removed, the plates are cleaned by a lead shot blasting machine equipped with a vacuum system to collect any particles released. New blocks are riveted onto the cleaned shoes; the blocks come from the manufacturer with holes for riveting. All rebuilding operations are automated. Workers in this facility wear dust masks, gloves, and goggles. Local ventilation is not used at this facility. The same procedures are used for both asbestos and non-asbestos brake blocks. The building housing this

operation has been monitored for asbestos; a company representative reports that a lower concentration of asbestos was found in the workplace than outside on the street (data was not provided to support this statement). Presumably, since the same procedures are used for both asbestos and non-asbestos, non-asbestos fiber concentrations would also be low.

3. Brake Block Replacement

Brake blocks for heavy vehicles are replaced about every two years.* Approximately 110 million drum brake blocks are sold annually as replacement parts.+ According to a representative of the American Trucking Association, the first step in replacement of truck brake blocks is removal of the wheel, with the tire and drum attached. The drum is wiped with a wet rag; the brake lining (still in the truck) and the brake parts are also wiped with a rag. If the brake block is asbestos, the rags are placed in plastic bags and disposed of as hazardous material. It is not clear how rags are disposed of when the brake block is non-asbestos. At least one manufacturer (Carlisle) recommends using asbestos procedures when handling their non-asbestos blocks; however, one of the selling points of non-asbestos brake blocks is the avoidance of asbestos procedures. Following the wiping step, the brake shoes are removed. Generally, the brake lining is not removed from the shoe; the whole assembly is sent to a rebuilder (see previous section). A new lining and shoe assembly or a rebuilt shoe is installed. All brake replacement procedures are manual and are performed in areas which are not locally ventilated.

In the past, it was common practice to grind truck blocks before installation for improved fit; however, this is rarely done now. According to

* ICF, op. cit., p. 19.

+ Ibid., p. 26.

an engineer with the American Trucking Association, if there were problems with the fit of the brake block, the mechanic would be more likely to grind the brake drum than the brake block. In addition, a mechanic at Sears Automotive Service reports that his facility formerly had a grinding wheel equipped with a vacuum dust collector for grinding truck brake blocks, but that now truck blocks are never ground. Mechanics servicing truck brake blocks are unlikely to use any protective equipment or clothing, according to the American Trucking Association.

D. Industrial Friction Materials

Some industrial friction materials, such as brake blocks for heavy equipment, are very similar to truck brake blocks, the major difference being only that brake blocks for heavy equipment may be much larger. Both asbestos and non-asbestos materials (such as fiberglass and aramid) are currently in used. Possible exposures to fibers from such materials are probably very similar to those from truck brake blocks; that is, mechanics replacing industrial brake blocks may be exposed to dust collected in the brake assembly during use of the brake. In addition, for industrial equipment used indoors, some wear-generated dust, which may contain fibers, may be released into the workplace. No data are available on the quantity and fiber content of the dust.

Another type of industrial friction material is the woven band brake, which is used on some types of construction equipment. According to a supplier of industrial friction material, this type of friction material is available in rolls. When replacement is required, the supplier cuts the material to size and attaches it to the brake plate. The same procedures are used for non-asbestos or asbestos material. Vacuum dust equipment is used to capture airborne dust and fibers, and workers wear dust masks.

E. Industry Contacts

The following industry contacts provided information on friction products during December-1985:

1. American Trucking Association
Larry Strawhorn
Engineering
Arlington, Virginia
2. Auto Parts Rebuilders Association
Bob Matthews
Technical Service
Detroit, Michigan
3. Barker Brake
Washington, D.C.
4. Bendix, Friction Materials Division
Alan Dunmore
Troy, New York
5. Carlisle Motion Control Industries
Bob Tami
Safety Engineer
Ridgeway, Pennsylvania
6. EIS Division of Parker Hannifin
Dave Radigan
Berlin, Connecticut
7. Industrial Brake and Supply
Jim Mayfield
Cincinnati, Ohio
8. Precision Import Service
Pete Vandervate
Owner
Fairfax, Virginia
9. Sears Roebuck and Co., Automotive Service
Luther Budd
Mechanic
Washington, D.C.

X. TEXTILE PRODUCTS -- SECONDARY MANUFACTURING

Textile products include clothing, yarn, tape and tubing, rope, cord, and braid. Fiberglass, ceramic, and aramid fibers are used as asbestos substitutes in the textile products; fiberglass is the most widely used substitute.

A. Use Areas

The end uses of textile products include the following:

- Fire-resistant materials: welding curtains, draperies, blankets, and protective clothing (used in the military, fire-fighting, and aerospace fields);
- Thermal insulation products: pipe wrap and protective coverings for hot glassware;
- Electrical insulation products: insulation of wires and cables;
- Packing and gasket products: pump packing; and seals for boilers, ovens, and furnaces;
- Friction materials: clutch facings and automotive brake pads.

Among these end-product applications, fire-resistant materials are of particular interest since there is a secondary process involved in making the final product (e.g., protective suits) where potential exposure may occur. Carded textiles* are used mainly in this product application. According to a textile specialist from Auburn Manufacturing Inc., carded textiles are softer than continuous filament textiles; therefore, carded textiles are often used in the fabrication of blankets and protective clothing.

In the other applications such as thermal insulation, electrical insulation, and packing/gasket products, the textile products from primary manufacturing (see Chapter V) are used "as is" without any modifications.

* Fiber size reduction occurs during manufacturing of carded textiles.

For example, ropes are used effectively in gasketing and seals, tapes are used in pipe wrap, and tubings are used in insulation of wires and cables. Continuous filament textiles* are used mainly for these applications (Auburn Manufacturing). Exposure to high fiber concentrations are unlikely under conditions of normal product use for these products; however, supporting exposure data are not available. For friction material applications, refer to Chapter IX for a more detailed discussion.

B. Manufacturing Process

Textile products such as tapes, ropes, tubings, and cords are used as end products. These are used "as is" for general uses, and secondary processing is not required. Yarns are intermediate products used to make fabric or cloth. The fabric is then processed to make end products such as welding curtains, blankets, fire-retardant suits, gloves, and mittens. Thread made from non-asbestos fibers is a finished product used to sew fabric for protective clothing and other heat-resistant applications.

During the manufacturing of non-asbestos fabrics, the fabrics are usually coated to provide the desired characteristics such as strength and rigidity. Coatings also serve to reduce airborne dust during secondary manufacturing (i.e., making fire-retardant suits). Types of coatings include organic-based phenolics, rubber, polyvinyl chloride, and polyvinyl acetate.

According to a General Manager from B&D Supply, Inc., textile cloth made from fiberglass is fabricated at B&D Supply to make end products such as blankets and welding curtains. The cloth is coated with rubber. The standard amount of coating applied is usually about the same as the weight of the uncoated cloth; however, this amount can vary slightly between companies.

* Fiber size reduction does not occur during the manufacturing of continuous filament textiles.

The manager of B&D Supply described the secondary process in making blankets and welding curtains as mainly cutting and sewing processes. The cutting process is usually automated using cutting machines and involves 2-3 operators per plant. Sewing is highly labor intensive. The workers use sewing machines to join the pieces of fabric together, and some fire-resistant material applications require sewing by hand. B&D Supply employs approximately 40 workers. The manager claims that only 10-15 employees are involved in fabrication process where exposure to durable fibers may occur.

Fyrepel Co. produces heat protective clothing for a wide variety of customers such as the steel industry, fire fighting services, and general use. Fyrepel uses both Nomex® fabric and Kevlar® fabric (made from DuPont's aramid fiber) for fire-resistant clothing; however, only the Kevlar® fabric is used as the substitute for asbestos fabric. The two main processes are again the cutting of the fabric into garment pieces and the sewing of the cut fabric into a garment. Fyrepel employs 35 workers but only 1-3 are involved in the cutting process (operating automatic cutting machines) and 10-15 employees are involved in the sewing process.

The secondary manufacturing processes for making non-asbestos final products such as welding curtains, blankets, gloves, mittens, and heat protective clothing are the same; the difference is in the design of the products. The general process is cutting of the textile into pieces and sewing the cut pieces together to make the final products. Personnel include cutters, sewing machine operators, hand sewers, and inspectors. The basic process is shown in Figure 5.

C. Exposure to Fibers

Data are not available on potential exposure during use of products such as tapes, ropes, tubings, and cords for thermal and electrical insulations,

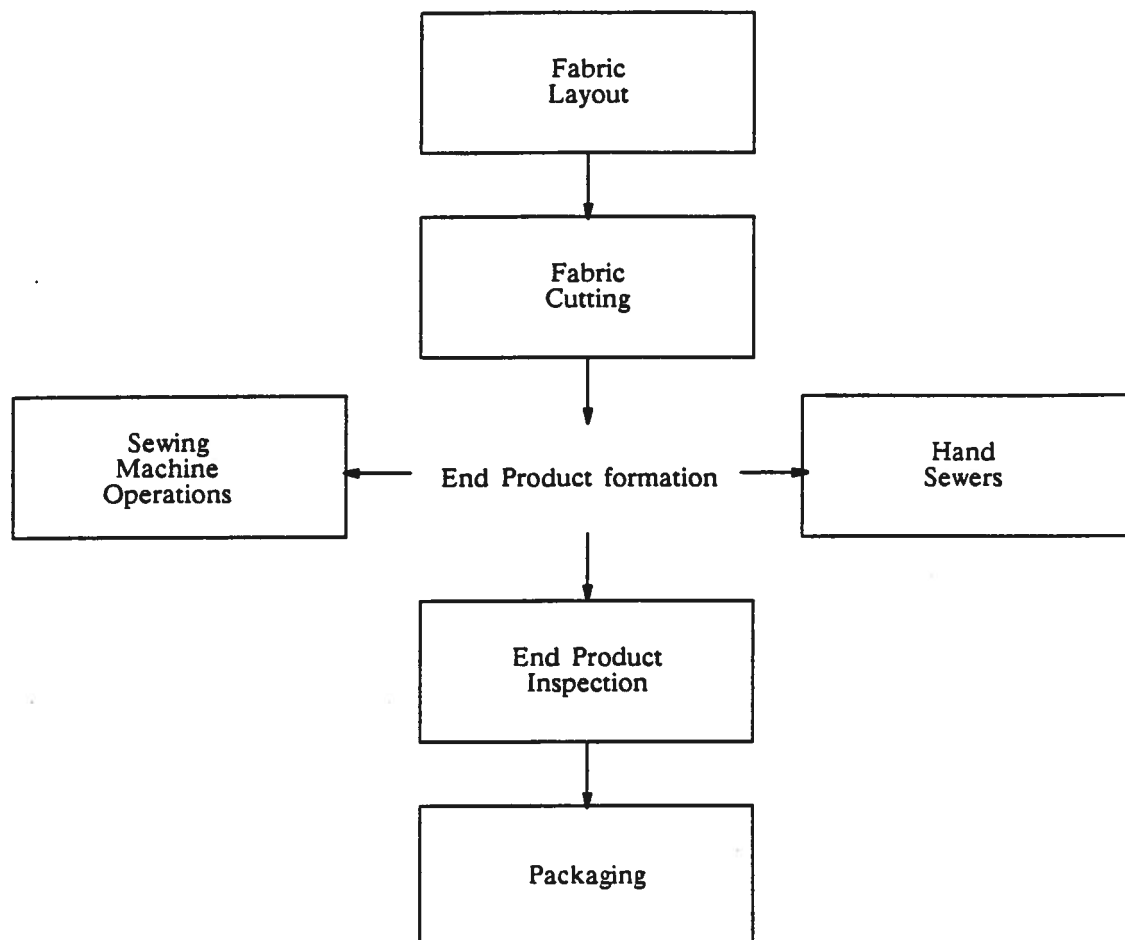


Figure 5. Secondary manufacturing process for fire-resistant products.

packing, and gasket applications. Exposure may result when abrasion occurs during the use of ropes and cords. However, these products are specially coated to prevent breakage of the fibers and to increase the durability of the product.

The process steps of fabric cutting and sewing allow for the greatest opportunity for airborne fiber emissions during manufacture of fire-resistant clothing. The manager of B&D Supply believed that although the fabric is encapsulated in rubber, breakage of the fibers is still possible and there would be exposure during the manufacturing process. B&D Supply claimed that by using a wet cutting process, the dust exposure should be minimal; however, B&D Supply has never monitored the workplace air for fibers. There are no engineering controls to ventilate local areas and to collect airborne fibers, only a general ventilation system is used. Workers involved in the cutting and sewing processes do not wear any personal protective equipment.

Fyrepel Co. claimed that its cutting process is automated, thus exposure is almost zero for its employees (data are not available to support this claim). The production manager claims that airborne dust levels at the plant are very low since the fabric used is coated (monitoring data are not available to support this statement). There are no dust collection systems at the plant for airborne fibers, and employees do not wear any personal protective equipment. Fyrepel commented that OSHA monitored the cutting area for airborne dust while Fyrepel still used asbestos fabric. OSHA did not detect any asbestos fibers in the air. When Fyrepel switched to non-asbestos products, the operations remained the same, so airborne dust is not considered a problem.

The Man-Made Fiber Producers Association was also contacted. The technical director on fire-retardant clothing commented that the exposure to

the fibers when using (i.e., wearing) the end products is very low, but no data are available to quantify "low".

The president of the United Textile Workers of America also commented that data about exposure during uses or during secondary processes are not available. The United Textile Workers of America has not received any complaints from its members concerning occupational exposures to fibers during the use of fire-resistant clothing made with durable fiber substitutes for asbestos.

D. Summary of Contacts

The following industry contacts provided information on textile products during December 1985:

1. Auburn Manufacturing Inc.
Cathy Leonard
Textile Products Specialist
Maine
2. B&D Supply, Inc.
Ted Brown
General Manager
Yeadon, Pennsylvania
3. DuPont, Haskell Laboratory
Bob Smith
Sales Representative of Nomex® - Protective Clothing Fabric
Wilmington, Delaware
4. Fyrepel Co.
Joe Walker
Production Manager
Newark, Ohio
5. Man-Made Fiber Producers Association
Dr. Pat Adams
Technical Director on Fire-Retardant Clothing
Washington, D.C.
6. New Tex Industry, Inc.
Sales Representative
Victor, New York

7. Rockland Fire Equipment
Production Manager
Nyack, New York
(No information provided)
8. Southern Manufacturing Co.
Doug Robertson
Vice President of Operations
Charlotte, North Carolina
(No information provided)
9. United Textile Workers of America
Francis Schaufenbil
President
Lawrence, Massachusetts

XI. REINFORCED PLASTIC MOLDING COMPOUNDS -- SECONDARY MOLDING

A. Introduction

Asbestos has been used in the manufacture of many types of reinforced plastic products, but is now used only with phenolic resins (a type of thermosetting plastic). Products made with asbestos are divided into "general" and "premium" categories, as follows:*

General: pot handles, various knobs and components of appliances (e.g., clothes washers and dryers, dishwashers, refrigerators, portable heaters, popcorn poppers, and broilers).

Premium: automobile brake and transmission components; commutators for electric motors, switches, and circuit breakers.

Asbestos is still being used to manufacture some premium products, specifically electric motor commutators (a commutator is the rotor around which the wire is wound in an electric motor) and friction products (see Chapter III). According to Rogers, a molding compound manufacturer, electric connectors have not been made with asbestos for many years; these are now mostly made with chopped-strand fiberglass. Electrical switchgears are also now mostly manufactured with fiberglass; the transition to fiberglass was completed two to three years ago. Asbestos use in commutators is also being replaced by fiberglass, according to the manufacturers contacted. No applications of Kevlar® or carbon fibers as asbestos substitutes were identified in premium molded plastic products (other than friction products).

Asbestos was being used in the manufacture of products in the general category as late as 1980; asbestos is no longer used in these products.+ All

* ICF, "Asbestos Products and Their Substitutes," July 11, 1984.

+ Nancy Krusell and David Cogley, "Asbestos Substitute Performance Analysis," February 1982.

manufacturers of general products contacted by ICF converted to non-asbestos molding compounds before 1978. The composition of the molding compounds now used is generally proprietary; they may contain natural minerals (e.g., talc, clay, mica) and/or manufactured fibers (e.g., fiberglass).^{*} No applications of Kevlar® or carbon fiber were identified in general products.

The manufacturing processes and emission controls for both premium molded plastic products (other than friction products) and general products are discussed in the next section. Potential fiber exposure is discussed in the following section.

B. Manufacturing Processes and Emission Controls

The basic steps in the manufacture of reinforced plastic parts are shown in Figure 6. Molding compound is received by the molding companies in containers (e.g., cartons, drums). Both manufacturers and users of phenolic molding compounds indicated that raw fibers are never used to manufacture plastic parts in this industry; molding compounds are used exclusively according to Rogers. Molding compound is conveyed either mechanically or pneumatically to a press in which parts are molded. Figures 7a and 7b illustrate the injection molding and transfer molding processes, which are the two most commonly used molding processes in this segment of the industry. In injection molding, the molding compound is transferred to a feed hopper, heated to the fluid state, and injected into a mold by a plunger or screw feeder. Additional heat and pressure "cure" the plastic part, forming a solid product. The part may require drilling, grinding, or other machining before final packaging. Transfer molding involves pumping resin under pressure into a mold which has been filled with reinforcing material.

^{*} ICF, 1984, op. cit.

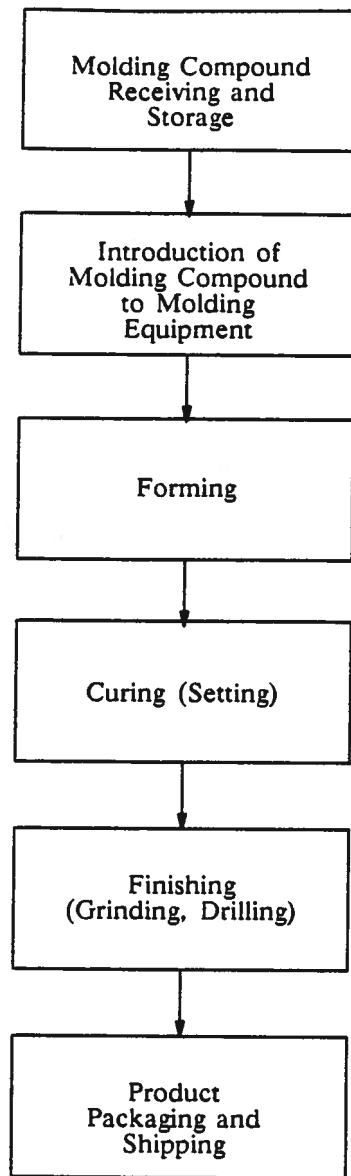


Figure 6. Reinforced plastic molding process.

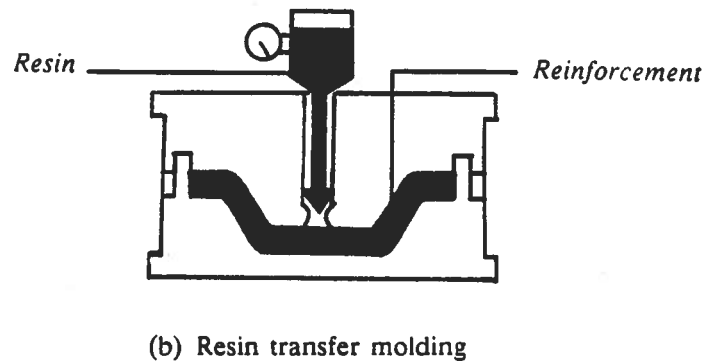
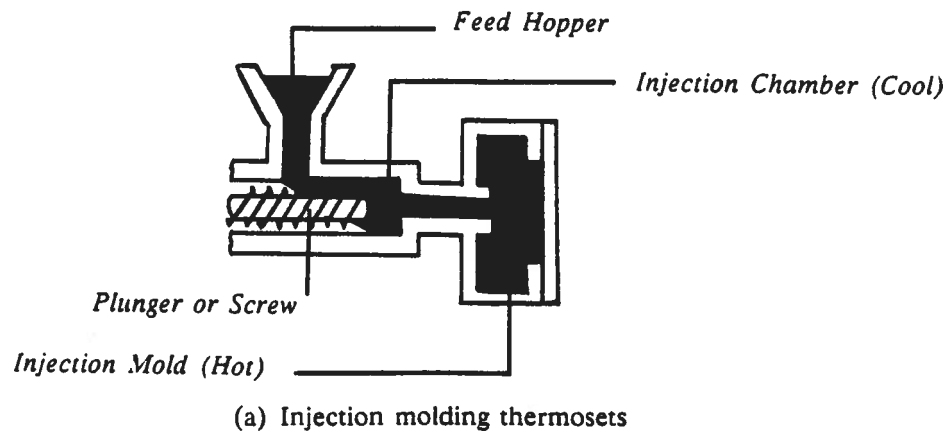


Figure 7. Injection and transfer molding.

The manufacturers and users of molding compounds contacted indicated, with few exceptions, that the equipment used in the manufacture of plastic parts is basically the same whether asbestos or substitute fibers are used. Resinoid's representative indicated that operational characteristics may differ with the fiber used, but he could offer no detailed information in this area. Of the users of molding compounds contacted, only Delco products experienced significant process equipment and procedure changes upon converting to non-asbestos compounds.

Delco products, a manufacturer of automotive parts and accessories, uses both asbestos and fiberglass in manufacturing electric motor commutators. Delco is in the process of converting all of their asbestos-using products to fiberglass, but Delco has found that conversion requires additional process steps and new process equipment. According to Delco, the molded fiberglass commutator requires a two-stage curing process. The part is molded and cured, and then washed in a series of baths to remove dust from the part (fiberglass was described as "very dusty" by Delco). The washed product is dried and then subjected to a post-cure in an oven. The asbestos-containing product requires only a single cure step.

Hoover Vacuum, a manufacturer of vacuum equipment, formerly manufactured electric motor commutators using asbestos, but Hoover converted to glass-filled products about two years ago. Hoover has not had to retool in converting to fiberglass, and little change was made in the manufacturing process. Material grade problems were experienced upon first converting to glass fiber, but Hoover was later able to obtain proper quality material for their manufacturing processes.

Both Hoover and Delco indicated that the molding compound is introduced into the feed hopper by a vacuum system. The vacuum system is semi-automated;

the molding compound is automatically transferred, but an operator must open the storage container and insert the vacuum hose. At Delco, the vacuum air, which is contaminated with fibers, is drawn into the plant central vacuum system. An operator manually changes the vacuum system filter periodically. Hoover uses a portable rotary air vacuum (venturi type). The air is exhausted to a filter which is manually replaced. The Hoover representative pointed out that they no longer handle asbestos.

Both Hoover and Delco have exhaust hoods on the commutator line. Delco has a total of 10 hoods (7 main hoods and 3 smaller hoods). These hoods exhaust to 55-gallon drums which are periodically replaced by a laborer. Hoover has hoods installed in the product finishing area. Both Delco and Hoover indicated that airborne dust levels and exposure to fibers are low (data were not available to support this statement).

In general, employees at Delco and Hoover do not wear protective equipment, although masks are available to all employees. At Delco, the laborer who changes the waste dust drums and vacuum filter usually wears a mask, and all maintenance personnel wear full protective gear. Both manufacturers have indicated that dust levels are low enough so that worker protection is not generally necessary (monitoring data are not available to quantify exposure).

The Lapcor Company, a manufacturer of thermoset plastic pot handles and other plastic parts, converted from asbestos-containing compounds to non-asbestos "general" molding compounds about eight years ago. Lapcor's suppliers, Plastic Engineering and Durez (a subsidiary of Hooker Chemical), replaced the asbestos in their molding compounds with proprietary substitutes. Lapcor does not have access to the composition of the molding compounds, and it is not known if the asbestos substitutes are fibers, non-

fibrous minerals, or a combination of the two. In this application, asbestos provided heat resistance, not strength, to the molded plastic part. Lapcor does not use the "high impact" molding compounds manufactured by Rogers and Fiberite Corporations.

Lapcor has indicated that their injection molding operation generates considerable amounts of dust, in large part from the materials handling area and the finishing area. Dust is controlled by vacuum hoods located at the materials handling and finishing areas, and also by a rapid-exchange building exhaust. Plant air is exhausted from the room, filtered, and recirculated (air is not directly exhausted as a large amount of energy would then be required to heat the building). Lapcor conducts periodic air (and noise) monitoring at the plant. Monitoring is conducted by the Lapcor's parent company (Mirro Corporation) in cooperation with their insurance company. A representative of Lapcor indicated that he did not believe Lapcor was required to monitor dust, but it does so anyway. Dust levels were described as "very low", but the monitoring data were not readily available to provide to us.

Sunbeam, a manufacturer of plastic parts for household appliances, converted from asbestos-containing compounds to non-asbestos compounds between 1971-1972. Sunbeam's major supplier of molding compound is Plastics Engineering. Sunbeam indicated that, after initial material grade problems were overcome by suppliers, no process modifications were required in the conversion away from asbestos.

Sunbeam has both transfer molding and injection molding processes using phenolic resins, and the processes are semi-automatic. Material hoppers are filled manually, and in some cases, product deflashing (finishing) is done by hand at a workbench. Deflashing is the removal of rough edges and excess material from the molded part. Sunbeam uses a "preform" process where the

molding compound pellets are compressed into bricks before introduction to the molding equipment; this is done using a transfer ram feeder. This preform area has a dust-collector, as do the hoppers and large deflashing equipment.

Sunbeam does not monitor dust at the plant. Generally, employees at Lapcor and Sunbeam do not wear dust protection equipment, with the exception of the preform operator at Sunbeam, who is required to wear a face mask.

C. Potential for Fiber Exposue

Manufacturers and users of phenolic molding compounds have indicated that the potential for exposure to airborne fibers is highest in introducing molding compound to the molding equipment (either mechanically or pneumatically) and in finishing the molded part (by drilling, machining, etc.). These two processes are typically manual; molding compound melting, injection molding, and curing are automated. Rogers indicated that the exposure probability when using granules and pellets is low if mechanical transport is used, and that the potential for exposure would be higher if pneumatic conveying systems are used. Rogers' representative has not seen exposure data for molding operations, but he considers it unlikely that such exposure would exceed the TLV. Resinoid indicated that airborne dust can be created by material transfer if the compound is scooped or shoveled; again no exposure data are available. Resinoid's representative indicated that it is difficult to keep glass fibers airborne, and he stated that they have been processing asbestos and fiberglass in the same facility for several years and have seen very little fiberglass in their plant air monitoring filters.

Both Hoover and Delco have conducted exposure monitoring when using asbestos. Seventy percent of the air samples at Delco were less than the detection limited (0.01 fibers/cc) and 30 percent of the samples range from 0.01 to 0.15 fibers/cc. The TLV for chrysotile asbestos is 2 fibers/cc; and

for crocidolite is 0.2 fiber/cc. At Hoover, asbestos dust levels were usually well below TLV, but Hoover discontinued regular monitoring after converting to fiberglass-filled products. Hoover now conducts dust surveys every year or so, but no data were made available to us.

At Hoover, a total of six employees work the commutator line each shift; two operators, who fill the hoppers and remove finished products from the line, and four product inspectors, who are removed from the process area. The Hoover line is fully automated, including the product finishing operation. Products are finished by drilling and reaming which generates minimal dust; however, the dust levels were not quantified. Delco has 31 operators, 4 inspectors, and 3 foremen on the commutator line each day (3 shifts per day). Monitoring indicates that all employees are subject to about the same level of dust exposure with the exception of the laborer who changes the waste drums and filters, and the maintenance crew. Again, information is not readily available on comparison of dust exposure levels before and after conversion to fiberglass, as Delco has only converted about 15 percent of their product line.

At Lapcor, a total of four employees operate 12 injection molding machines. The line is fully automated and not "operator oriented," and the four operators are responsible for all aspects of the line operation, including mold changes and quality control. The Sunbeam molding lines are staffed by 50-60 people (25-30 per shift). One employee each shift works in each of the preforming and finishing areas. As previously discussed, materials handling and finishing are primarily manual operations. Sunbeam does not monitor dust levels at the plant. (Hoover, Lapcor, and Delco all monitor dust levels, but they did not provide us with their data.)

D. Carbon Fibers as an Asbestos Substitute

Hercules and Celion/BASF, two carbon fiber manufacturers, were contacted to obtain information on the uses of carbon (graphite) fibers in various industries. A representative of Hercules explained that "carbon fiber" and "graphite fiber" refer to basically similar materials. Both are made by similar processes, but carbon fibers have less strength than graphite fibers because more of the carbon is in crystalline form in the graphite fiber. Hercules identified two areas where carbon fibers have been substituted for asbestos. Substitution of carbon fibers for asbestos is being done by aircraft brake lining manufacturers at this time. According to Hercules, the manufacture of high strength/high temperature belts from reinforced rubber using carbon fiber instead of asbestos is still in the development stage. Celion identified brake linings, packing, gaskets, and protective clothing as areas where asbestos has been replaced by carbon fiber.

Both Hercules and Celion indicated that the primary use of chopped strand carbon fiber in molded plastic products is in sports equipment, which is not an asbestos substitute application. Celion indicated that asbestos in molded plastic products has generally been replaced by clay, mica, and various thixotropes. Carbon fiber is used in molded plastic products to obtain the properties of electrical conductivity, mechanical strength, and lubricity. Asbestos does not illustrate these properties in molded plastic products, and carbon is, therefore, not a substitute for asbestos in this application. According to Celion, carbon fiber, at about \$20 per pound, is also much too expensive for general use in molded plastic products.

E. Industry Contacts

The following industry contacts provided information on reinforced plastic molding operations during November and December 1985:

1. Celanese Corporation-Celion Division
(Now Celion Corporation, Division of BASF)
Jim Lewis
Sales Engineer
Chatam, New Jersey
2. Certain-Teed Corporation
Customer Inquiries Department
Valley Forge, Pennsylvania
(No information provided)
3. Delco Products
(Division of General Motors)
Bob Johnson
Rochester, New York
4. Garfield Molding Co.
David Defone
Garfield, New Jersey
(No information provided)
5. General Electric
Carbon Products Operations
Manufacturing
Erie, Pennsylvania
(No information provided)
6. General Industries
Darryl Hastings
Manufacturing
Elyria, Ohio
(No information provided)
7. Hercules Corporation
Larry Glaser
Sales Representative
Magna, Utah
8. Hoover Vacuum
Mr. Mateko -- Manufacturing
Mr. Daffinata -- OSHA Liaison
North Canton, Ohio
9. Lapcor Plastics
Don Bohne
Purchasing Agent/Manufacturing
Monitowoc, Wisconsin
10. Plastic Engineering
Lewis Karb
Sheboygan, Wisconsin

11. Resinoid Engineering
Bob Dennis
Skokie, Illinois
12. Rogers Corporation
Ray Mikulak
Operations Manager
Manchester, Connecticut
13. Sunbeam Corporation
Mr. Paine
Manufacturing
Holly Springs, Mississippi

APPENDIX A. ASBESTOS PRODUCTS AND FIBER SUBSTITUTES

This appendix describes products made from asbestos and substitute products made from other durable fibers. The source of the information in this appendix is ICF's 1984 report, Asbestos Products and Their Substitutes. Table A-1 lists the 30 asbestos products along with substitute fiber product names, durable fibers used in these substitute products, and non-fiber substitute products. The 30 asbestos products are assigned to one of seven product categories for this analysis as shown in Table A-1. The asbestos product categories and the substitute products are discussed below.

A. Paper and Felt Products

1. Felt Products

Asbestos felt products include roofing felt (saturated and unsaturated); flooring felt; and pipeline wrap, particularly for underground oil and gas pipelines. Asbestos is used in these products for its dimensional stability and resistance to moisture, rot, and heat. Fire resistance is also an important property for roofing felt; and resistance to corrosion and chemicals, as well as heat resistance, is important for pipeline wrap. Asbestos roofing and flooring felt may be out of production in this country.

Other fibers are available as substitutes for all applications of asbestos felt. Organic felts, made from cellulosic fibers, are used for roofing and flooring applications. Fiberglass felts are used for roofing, flooring, and pipeline wrap. Ceramic fiber products are also available for flooring felts.

In addition to fiber products, non-fiber alternatives are available for all asbestos felt applications. Plastic membranes and various types of tiles are available for roofing applications. Foam backings and sheet vinyl flooring without backing may be used for flooring. Non-fiber substitutes for pipeline wrap include enamels, extruded plastics, and thermosetting resins.

Table A-1. Asbestos Products and Substitutes

| Product Category | Asbestos Product | Substitute Product Made with Fiber | Name of Fiber(s) | Non-Fiber Substitutes |
|--|---|---|---|--|
| Paper and Felt Products | Asbestos Flooring Felt (may be out of production) | Fiberglass felt Organic felt Pulpex | Fiberglass Cellulose Polyethylene or polypropylene Nylon based cellulose Ceramic | Foam-cushioned backings Backless sheet vinyl flooring |
| | | Bontex 148 Duracon | | |
| | Asbestos felt-backed vinyl sheet flooring | Fiberglass felt-backed Pulpex Bontex Ceramic fiber-backed Organic felt-backed | Fiberglass PE or PP (Pulpex) Nylon/cellulose (Bontex 148) Ceramic (Duracon) Cellulose | Foam-cushioned backings Backless sheet vinyl flooring |
| | | | | |
| | | | | |
| | Saturated Roofing Felt | Organic felt Fiberglass felt | Cellulose Fiberglass | Tile roofing Single-ply membrane |
| | Unsaturated Roofing Felt | Fiberglass felt Polyester felt | Fiberglass Polyester | Tile roofing Single-ply membrane |
| | Pipeline wrap | Fiberglass mat | Fiberglass | Extruded plastics (polyethylene & polypropylene) Fusion-bonded Thermosetting resins Coal tar epoxy Concrete Liquid epoxy Liquid phenolics Wax coatings Polyurethane foam |
| | | Corrosshield & Safelt Enamel coatings Plastic tape | Not specified Fiberglass Polyethylene | |
| | | | | |
| Specialty papers | | | | |
| a. Beverage and pharmaceutical filters | | | | |
| b. Cooling tower fill | | | | |
| c. Diaphragms for electrolytic cells | | | | |
| | | | Cellulose | Wood Polyvinyl chloride Galvanized steel Stainless steel Ceramic tile Mercury cells Membrane cells (perfluorocarbon membranes) |

Table A-1 (Continued)

| Product Category | Asbestos Product | Substitute Product Made with Fiber | Name of Fiber(s) | Non-Fiber Substitutes |
|-------------------------------------|--|--|---|--|
| Paper and Felt Products (continued) | High-grade electrical paper | Nomex paper Fiberfrax | Aramid Ceramic Fiberglass (in combination with other materials) | |
| | Beater-add gaskets | | Ceramic Cellulose Aramid Proprietary fiber mixtures Teflon | Silicone rubber All-metal gaskets |
| | Millboard | Fiberfrax | Ceramic Mineral wool Fiberglass Ceramic | |
| | Rollboard (asbestos product may be out of production in U.S.) | Other ceramic boards Mineral board | | |
| | Commercial paper (asbestos commercial paper no longer in production in U.S.) | Fiberfrax Kaowool | Ceramic Kaolin | |
| | Corrugated Paper (asbestos no longer used in U.S.) | Fiberglass paper Lytherm Kaowool SAFEIL Fiberfrax | Fiberglass Ceramic Ceramic Alumina fibers Ceramic | |
| | | "Thermo 12", "Kaylo" | Ceramic Wollastonite Fiberglass "Organic fiber" | |
| | | | | |
| | | | | |
| | | | | |
| Friction Materials | Brake blocks (for heavy-duty vehicles) | Non-asbestos brake blocks | Aramid Fiberglass Processed mineral fibers (used with other fibers) Steel wool | |
| | Clutch facings | Metallic & semi-metallic brake blocks (only for very heavy-duty use) | Fiberglass Aramid | Sintered metal (heavy duty vehicles) |
| | Automatic transmission components (friction clutch plates) | | Cellulose Aramid Fiberglass | Sintered metal (for heavy-duty vehicles) |

Table A-1 (Continued)

| Product Category | Asbestos Product | Substitute Product Made with Fiber | Name of Fiber(s) | Non-Fiber Substitutes |
|--|--|--|--------------------------------------|--------------------------|
| Friction Materials (continued) | Disc Brake Pads (Heavy vehicles) | Semi-metallic disc brake pads | Steel wool | |
| | Disc Brake Pads (Light & medium vehicles) | Semi-metallic disc brake pads | Steel wool | |
| | | Non-asbestos organic (NAO) disc brake pads | Aramid (Possibly fiberglass as well) | |
| | Drum Brake linings (Light & medium vehicles) | Non-asbestos organic (NAO) drum brake lining | Aramid (Possibly fiberglass as well) | |
| | Friction materials (industrial & commercial) | Semi-metallic drum brake linings | Steel wool | |
| Liquid Products | | Friction materials | Fiberglass | Sintered metals |
| | | | Aramid | |
| | | | Steel wool | |
| | | | | |
| | | | | |
| Adhesives and sealants | a. Roofing cement & flashing cement | Roofing & flashing cement | Polypropylene (Pulpex) | |
| | | | Cellulose | |
| | | | Acrylic homopolymer | |
| | | | High-density polyethylene (SWP) | Vinyl plastisol products |
| | | | Cellulosic (Kayocel) | Vinyl sealants |
| | | | PE or PP (Pulpex) | |
| | | | Fiberglass a | |
| | | | Fibrous alumina a | |
| | | | Magnesium silicate fibers a | |
| | | | | |
| Automobile under-coatings and sealants | | Automobile under-coatings & sealants | Acrylic homopolymer | Silicone sealants |
| | | | PE or PP (Pulpex) | |
| | | | Cellulosic (Kayocel) | |
| Caulks and sealants | | Caulks & sealants | "Mineralized wool" a | |
| | | | Mineral wool a | |
| | | | Steel a | |
| | | | Carbon a | |
| | | | Nylon a | |
| | | | Ceramic a | |

Table A-1 (Continued)

| Product Category | Asbestos Product | Substitute Product Made with Fiber | Name of Fiber(s) | Non-Fiber Substitutes |
|-----------------------------|---|--|---|--|
| Liquid Products (continued) | Paints and surface coatings (asbestos no longer used in paints) | | | |
| | a. Paints (texture) | Rayon Hemp | Fiberglass Cellulose Cellulose Polyolefins Nylon Acrylic Homopolymer | Clay Talc Mica Calcium carbonate Barite |
| | b. Roof coatings | | Polypropylene (Pulpex) Cellulosic Fiberglass Acrylic Homopolymer | Single-ply membrane Barite |
| | c. Pipe coating | Plastic tapes | Unspecified fibers | Concrete Polyurethane foam Wax Coatings Extruded plastics (polyethylene, polypropylene) Epoxies and phenolics Enamels |
| | d. Chemically resistant coatings & linings | | | Talc Barite Diatomite Silica Clay Mica Epoxy coatings |
| Textile Products | | | | |
| Asbestos textiles | a. Asbestos cloth | Glass fiber Aluminized glass fiber PBI Kynol Nomex Kevlar Ceramfab | Fiberglass Fiberglass Polybenzimidazole Phenol formaldehyde polymer Aramid fiber Aramid fiber Ceramic fiber Silica | |

Table A-1 (Continued)

| Product Category | Asbestos Product | Substitute Product Made with Fiber | Name of Fiber(s) | Non-Fiber Substitutes |
|------------------------------|---|---|---|--|
| Textile Products (continued) | b. Other asbestos textiles | | Fiberglass Aramid fibers Ceramic fibers | |
| | c. Dryer felt (asbestos no longer used) | | Fiberglass Aramid Polyester Acrylic | |
| Rolled Products | Asbestos sheet gasketing | Sheet gasketing | Aramid Teflon fiber Graphite Silica Ceramic Glass Cellulose Acrylic | |
| | Asbestos packing | Teflon Graphite fibers Flax | Aramid Polytetrafluoroethylene Graphite Fiberglass Cellulose Graphite/Teflon composite | |
| | Vinyl-Asbestos Floor Tile | Asbestos-free Vinyl composition floor tile | Fiberglass Polyethylene or polypropylene (Pulplex) Cellulose (Santoweb) | Calcium carbonate Limestone Solid vinyl/tile Rubber tile Ceramic tile Wood Carpeting |
| | Asbestos-Cement Pipe | | - | Polyvinyl chloride pipe Ductile iron pipe Prestressed concrete pipe Reinforced concrete pipe |
| | Corrugated asbestos-cement (A/C) sheets | Fiberglass-reinforced cement (GRC) sheet Fiberglass-reinforced plastic (FRP) sheet | Fiberglass Fiberglass | Aluminum siding and roofing Steel panels masonry |

Table A-1 (Continued)

| Product Category | Asbestos Product | Substitute Product Made with Fiber | Name of Fiber(s) | Non-Fiber Substitutes |
|--------------------------------------|-----------------------------------|--|---|--|
| Asbestos-Cement Products (continued) | Flat asbestos-cement (A/C) sheets | Flat GRC sheet Glass-reinforced stabilized clay Flat FRP sheet | Fiberglass Fiberglass Fiberglass | Alumina sheet Laminated hard board Cement/wood board Polypropylene layered cement sheet Calcium silicate cement Epoxy resin Laminated plastic Alberene stone Resin-impregnated sandstone |
| | Asbestos-cement (A/C) shingles | Asphalt-fiberglass shingles Cedur Shake | Fiberglass Fiberglass | Cement tiles Particle board Cedar roofing and siding Metal siding Precast Concrete Aluminum siding Vinyl Stucco Brick |
| | Asbestos-reinforced plastics | Reinforced plastics | Fiberglass Carbon fiber Processed mineral fiber (PMF) Wollastonite Aramid | Talc Clay Mica |

^a Possible substitutes; may not be in use.

Sources: ICF: 1984 (July 11). Asbestos products and their substitutes.
ICF: 1985 (May 1). Substitution analysis for asbestos brake linings for on-road vehicles.

2. Paper Products

Paper products include commercial paper (general insulation paper and muffler paper), -corrugated paper (used for insulation), high grade electrical paper, millboard, rollboard, beater-add gasketing (used to seal connections in piping and other joints), and specialty papers (beverage and pharmaceutical filters, cooling tower fill, and diaphragms for electrolytic cells). Asbestos commercial paper, corrugated paper, and rollboard are no longer produced in the U.S.

Products made with fiber substitutes are available for all paper products except cooling tower fill and diaphragms for electrolytic cells, for which there are non-fiber substitutes only. Substitutes for asbestos commercial paper and asbestos corrugated paper include paper made from ceramic fiber, fiberglass, and calcium silicate. Cellulose fiber paper may be used for some purposes, but it does not withstand heat well enough for many insulation applications. Asbestos rollboard has been entirely replaced by ceramic rollboard. High-grade asbestos electrical paper is used for insulation and fire protection in heavy electrical equipment with high operating temperatures. Fiber substitutes include aramid fibers (used in Nomex® paper, probably the most widely used substitute) and ceramic fibers. Fiber substitutes for asbestos in millboard include ceramic fiber, mineral wool, and fiberglass; asbestos millboard is considered superior for some applications because of its resistance to heat and corrosion. For gaskets, aramid, tetrafluoroethylene (Teflon®), graphite, silica, ceramic, glass, and cellulose fibers may be used as asbestos substitutes in various applications. In the specialty paper category, asbestos filter paper, used for the removal of haze from liquids, can be replaced by cellulose paper filters.

Only non-fiber substitutes are available for two products in the specialty paper category. Asbestos cooling tower fill can be replaced for high temperature use by galvanized steel, stainless steel, or ceramic tile. Asbestos diaphragms for electrolytic cells for the production of chlorine cannot be replaced by another type of diaphragm, but a different type of cell can be used; membrane cells and mercury cells are available.

B. Friction Materials

Friction products include clutch plates for automatic transmissions, clutch facings for manual transmissions, automotive brake linings (brake blocks for heavy vehicles; disc brake pads for heavy, light, and medium vehicles; and drum brake linings for light/medium vehicles), and industrial and commercial friction materials for brakes and clutches. Asbestos is used in these products for its strength, resistance to wear, heat resistance, and ease of processing. These products generally consist of a fiber material (asbestos or substitute) in an organic binder; however, there are also some woven industrial friction products, such as band brakes for heavy machinery.

Substitute fibers used in friction products include aramid fibers and fiberglass (used in all types of brake linings and in industrial and commercial friction materials), and steel wool (used in disc brake pads and specialized brake blocks and in industrial and commercial friction materials). Mineral fibers, ceramic fibers, and other fibers are also sometimes used. Carbon fibers are used in airplane brakes and some industrial friction products. Aramid fibers wear longer than asbestos fibers, but are more difficult to process and are much more expensive. Steel wool fibers (in disc brake pads for light/medium vehicles) have mainly replaced asbestos for front disc brakes on front-wheel drive vehicles, but are unsatisfactory for low-temperature use. Fiberglass fibers cannot withstand high temperatures.

There are non-fiber substitutes for asbestos in a few applications of friction products, such as sintered metals for heavy duty industrial friction products.

C. Liquid Products

Liquid products include adhesives, such as roofing, flashing, and tile cements; sealants, such as vehicle undercoatings and caulks and joint compounds; asphalt surface coatings for roofs (the primary use of asbestos in this category); and chemically resistant coatings and linings. Asbestos has been used in the past for texture paints and patching compounds but is no longer used for these applications. Asbestos is particularly desirable for use in asphalt roofing cements and surface coatings because it disperses uniformly in asphalt, provides weather resistance, vermin resistance, and viscosity control, and reinforces the asphalt and protects it from cracking. Asbestos is used in caulks and sealants for its strength and durability, waterproofing properties (desirable in some applications), heat and decay resistance, and noncombustibility. The same properties are useful for surface coatings; the resistance of asbestos to most chemicals is important in chemically resistant coatings and linings.

Fiber substitutes available for asbestos roofing cement and roof coatings, the primary liquid products made from asbestos, include polypropylene, cellulosic fibers, fiberglass, and acrylic homopolymer. The substitute fibers are generally considered inferior to asbestos for roofing products. Currently, asbestos is not widely used in caulks, adhesives, and sealants. Cellulosic fibers and polyolefin fibers are available as substitutes for these uses. Carbon fibers are used in aircraft adhesives and sealants. For automobile undercoatings and sealants, olefin fibers, fiberglass, fibrous

alumina, and magnesium silicate, and coatings without fibers are possible substitutes. Asbestos has been banned for use in spackle and dry wall joint compounds; fiber substitutes such as attapulgite clay and carboxymethylated cellulose are used in this application. For texture paints, where asbestos has also been banned, fiberglass, rayon, hemp, polyolefins, clay, talc, and other fibers may be used.

Chemically resistant coatings and linings such as pipe coatings containing asbestos have primarily non-fiber substitutes such as extruded plastics, thermosetting plastics, epoxies, phenolics, and enamels.

D. Textile Products

Asbestos textile products are asbestos cloth and other textile products such as thread, yarn, lap, roving, cord, rope, and wick. Asbestos cloth is used principally for fire resistant materials and thermal and electrical insulation. Other asbestos textile products are used for insulation, packing and gasketing, and production of asbestos cloth.

Substitutes for asbestos in textiles must be heat resistant and flexible. The major fiber substitute for asbestos textile products is fiberglass, although fiberglass cannot be used at temperatures as high as asbestos, and its tensile strength is not as high. Aramid fibers and ceramic fibers are also substitutes for asbestos in textile products; these materials can be used at higher temperatures than asbestos.

E. Rolled Products

Rolled products include compressed sheet gasketing, packing, and vinyl composition floor tile. Asbestos compressed sheet gasketing is used to seal connections in piping and joints, as are beater-add gaskets (discussed in the Paper and Felt Products section). Compressed sheet gasketing is used instead

of beater-add gaskets for heavy duty use because it has higher density and greater tensile strength than beater-add gasketing. Asbestos packings seal one fluid from another in applications in which fluid motion takes place, such as valves and pumps. Asbestos packings may be produced by lubricating yarn and then braiding and calendering, or by variations of this process. Asbestos is used for gaskets and packing because of its resistance to heat, its strength and resilience, and its relative chemical inertness. Asbestos is used for reinforcement in floor tile for its resistance to abrasion and indentation; dimensional stability; durability; flexibility; and resistance to moisture, hot, oil, grease, acids, alkalies, and other substances.

A number of fiber substitutes for asbestos in gaskets and packing are available. Aramid fibers are very strong and can be used up to 500°F. polytetrafluoroethylene (Teflon®) fiber can be used up to 500°F and is resistant to most chemicals, but expands on heating. Graphite fiber is very heat resistant (up to 5,000°F) and is resistant to chemicals. Silica fiber can be used at high temperatures, is resistant to many chemicals, and has high tensile strength. Ceramic fibers can withstand temperatures up to nearly 3,000°F, retain flexibility and resiliency at high temperatures, and have higher compressive strength than asbestos; however, it is difficult to produce homogenous mixtures of ceramic fibers. Glass fibers are strong and can withstand temperatures up to 1,100°F. Cellulose fibers may be used at temperatures below 300°F. There are some other proprietary synthetic fibers available for gasketing use; it is possible that there are some non-fiber (probably plastic) materials available also. Fiber substitutes for asbestos in vinyl floor tile include fiberglass, polyethylene/polypropylene, and cellulosic fibers. Non-fibrous fillers and reinforcing materials are also used.

F. Asbestos-Cement Products

Asbestos-cement products include pipe, used primarily for water mains and sewer lines; corrugated sheets, used primarily as siding and roofing for factories, warehouses, and agricultural buildings, and as lining for waterways and canal bulkheads; flat sheets, used for walls in factories and agricultural buildings, paneling, laboratory table tops, and other uses; and shingles for siding and roofing. Asbestos is used as reinforcement in these cement products because of its strength, flexibility, thermal resistance, and chemical inertness. The resulting asbestos product is rigid; durable; noncombustible; and resistant to heat, weather, and corrosive chemicals.

There are no fiber substitutes for asbestos in asbestos cement pipe. For other asbestos cement products, fiberglass is the most commonly used fiber substitute. Corrugated and flat fiberglass-reinforced cement sheets can substitute for asbestos cement products in many applications; fiberglass reinforced plastic sheet is satisfactory for some uses also. Fiberglass-based asphalt shingles may substitute for asbestos cement shingles for roofing use.

A number of non-fiber substitutes are available for asbestos-cement products. In place of asbestos-cement pipe, polyvinyl chloride pipe (the most important substitute), ductile iron pipe, prestressed concrete pipe, and reinforced concrete pipe (reinforced with steel bars and/or welded wire mesh) may be used, depending on the application. Aluminum, steel, and masonry can substitute for corrugated asbestos-cement sheet; laminated hardboard, cement/wood board, polypropylene layered cement, and other materials can be used in place of flat asbestos-cement sheet. For laboratory desk tops and fume hood benches, one application of asbestos-cement sheet, epoxy resin, laminated plastic, albarene stone, and resin-impregnated sandstone may be used.

G. Reinforced Plastic Products

Plastic products reinforced with asbestos are predominantly phenolic molding compounds. Asbestos is used in these compounds because it retains its strength at temperatures above 500°F and has high impact strength and dimensional stability.

Fiberglass is the primary substitute for asbestos in phenolic molding compounds; other fiber substitutes include carbon fiber (which cannot be used where electrical insulating properties are required), aramid fiber, processed mineral fiber, and wollastonite. Clay, talc, and mica, which may in some cases be fibrous, are also used as substitutes.

APPENDIX B. GLOSSARY

Acrylic Fiber. Generic name for a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85 percent acrylonitrile units ($-\text{CH}_2\text{CH}(\text{CN})-$) by weight.

Aramid Fiber. Generic name for a distinctive class of highly aromatic polyamide fibers. Kevlar®, the trade name used by DuPont for this product, pulp most frequently replaces asbestos. Kevlar® pulp is composed of short fibers with fine fibrils attached to the surface in a wood-like-substructure. These fibrils are highly aligned, strong crystallites bonded along the fiber axis. Abrasion can peel these fine fibrils from the fiber surface in the form of curled and branched ribbon-like material; quite unlike the straight, needle-like forms of asbestos, glass, and mineral fibrils. Short pulp fibers are 0.5 to 8 millimeters in length and 12 microns in diameter. Kevlar® pulp abraded using a micro-jet produces ultrafine fiber; 60 to 70 percent of the fibers are 10-30 microns in length and less than 1 micron in diameter.

Carbon Fiber. Carbon fibers have moderate tensile strength and are produced mainly from polyacrylonitrile. The composition of carbon fiber is very similar to graphite fibers; the major difference between carbon and graphite fibers is in the tensile strength of the fibers. (See graphite fiber.)

Cellulose. A natural carbohydrate high polymer (polysaccharide). Cotton fibers are almost pure cellulose; wood contains about 50 percent cellulose.

Ceramic Fiber. Ceramic fibers are aluminum silicate fibers. Ceramic fibers are generally produced with a nominal diameter of 2-4 microns with a range of individual diameter from 0.5 to 12 microns -- skewed towards the larger diameter fibers.

Durable. Fibers which are non-biodegradable and can survive in biological systems for long periods of time.

Fiber. A fundamental form of solid (usually crystalline) characterized by relatively high tenacity and an extremely high ratio of length to diameter (several hundred to one). Natural fibers come from animals (e.g., wool and silk made of protein), vegetables (e.g., cotton made of cellulose), and minerals (e.g., asbestos). Cotton fiber is called staple and rarely exceeds 2 inches in length.

Fiberglass®. A variety of products made of or with glass fibers or glass flakes including insulating wools, mats and rovings, coarse fibers, acoustical products, yarns, electrical insulation, and reinforced plastics.

Fibril. Fibrils are fine threadlike material into which a fiber can be longitudinally split.

Fibrous Glass. A manufactured fiber in which the fiber-forming substance is glass. Glasses are a class of materials made from mixtures of silicon dioxide or oxides of various metals and other elements that solidify from the molten state without crystallization. Fibrous glass fibers will break perpendicular to the length of the fiber but not longitudinally into thinner fibers.

Filament. A filament is a continuous fiber usually made by extrusion through a spinneret (e.g., nylon, glass, polyethylene). In the textile field, many filaments are often twisted together to form yarn.

Graphite Fiber. Graphite is a crystalline form of carbon. Graphite fibers have high tensile strength (50,000 to 150,000 psi) and are made from rayon or polyacrylonitrile.

Inorganic/Synthetic Fiber. Fibers which include fibrous glass, mineral wool, ceramic fiber, and carbon/graphite fibers.

Kaowool®. Trademark for a stable, high-temperature alumina-silica ceramic fiber. Kaowool® can be used up to 2300°F; its melting point is 3200°F. The diameter of the fibers is 2.8 microns, and the length of the fibers can be as high as 10 inches. Kaowool® is used as an insulating material.

Kevlar®. Trademark for an aromatic polyamide fiber (terephthalamide, poly-1, 4-phenylene) of extremely high tensile strength and greater resistance to elongation than steel. Kevlar® is used as a reinforcing material for plastic composites.

Nylon. Generic name for a family of polyamide polymers characterized by the presence of an amide group (-CONH). Nylon fibers are crystalline, thermoplastic polymers.

Olefin Fibers. A manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 85 percent of ethylene, propylene, or other olefin units by weight.

Organic/Synthetic Fiber. Fibers which include aramid fibers, polyethylene pulp, and polypropylene pulp and fibers.

Polybenzimidazole. A synthetic polymer $(C_7H_6N_2)_n$ designed for high-temperature applications. Polybenzimidazole is reputed to withstand temperatures up to 500°F for 1000 hours.

Polyester. Generic name for a manufactured fiber in which the fiber-forming substance is any long chain synthetic polymer composed of at least 85 percent of an ester of a dihydric alcohol and terephthalic acid by weight. The structure in most polyester fiber is polyethylene terephthalate. Fiber size varies from 1 to 1000 microns in length and 1 to 40 microns in diameter.

Polyethylene Pulp. A very fine, highly branched, discontinuous, water-dispersible fiber. This pulp has an irregular surface with crevices which appears film-like. Average lengths of pulp fibers are one millimeter, with a maximum length of 2.5 to 3 millimeters. Pulp diameters range from 5 to 40 microns.

Polypropylene Pulp and Fibers. Synthetic pulp with an irregular surface containing numerous crevices and having a bright, film-like appearance. Staple fibers of polypropylene are smooth rods of solid polymer; average lengths are generally one millimeter with a maximum length of 2.5 to 3 millimeters, diameters are 5 to 40 microns.

Respirable. Fibers with diameters less than 3 microns which can enter the small airways leading to the lungs.

Teflon®. Trademark for tetrafluoroethylene (TFE) fluorocarbon polymers available as molding and extrusion powders, aqueous dispersions, films, finishes, and multi-filament yarns or fibers. The name also applies to fluorinated ethylene-propylene (FEP) resins available in the same forms. Fibers are monofilaments made from copolymers of TFE and FEP.

Wollastonite. Wollastonite is a natural fibrous calcium silicate (CaSiO_3) found in metamorphic rocks. Wollastonite is used in ceramics and as a substitute for asbestos in wallboard and brake linings.

Wool. Staple fibers, usually 2 to 8 inches long, obtained from the fleece of sheep. Wool fibers have the ability to cling together when spun into yarns. Chemically, wool consists essentially of protein chains bound together by disulfide cross linkages.